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CONTENTS

I. INTRODUCTION

The species of *Gracilaria* are, as a whole, widely distributed in the northern hemisphere from the Arctic Ocean to the tropical seas and even in the southern hemisphere. The genus *Gracilaria* was established by Greville in 1830, when it was defined as comprising the following four species: *G. confervoides*, *G. compressa*, *G. purpurascens* (now placed in *Cystoclonium*) and *G. erecta* (now placed in *Cordylecladia*). In 1852 J. Agradh revised and redefined the genus designating *G. confervoides* as its type species. Lately *G. confervoides* and *G. compressa* were revised as *G. verrucosa* (Huds.) Papenfuss (1950) and *G. bursa-pastoris* (Gmel.) Silva (1952) respectively. Since the publication of the just mentioned work of J. Agardh, a good number of new species amounting to more than one hundred and fifty in number have been added to the genus by various authors and at the same time many other species were replaced from this genus to other genera. Of these authors the following are to be mentioned here: Börgesen (1920, 1929, 1934, 1943, 1950, 1952, 1953), Setchell et Gardner (1924), Sjöstedt (1926), Taylor (1928, 1945, 1947, 1954), Kylin (1930, 1932, 1941), Yamada (1933, 1938, 1941), Smith (1944) and Dawson (1944, 1945, 1945a. 1949, 1952, 1953, 1953a, 1954, 1954a).

A detailed anatomical study of *Gracilaria* was first made by Sjöstedt (1926) with *G. confervoides*, *G. compressa* and *G. robusta*. In the last mentioned species, which was later recognized by Kylin (1930) as a new species and was named *G. sjöstedtii*, the cystocarp was described by Sjöstedt to show several striking characters differing

from those in the other two species. The peculiarity of *G. sjöstedtii* thus elucidated was later considered by Dawson to be of generic importance, and he established *Gracilariopsis* for that species and other related ones in his monographic work on the Northeast Pacific Gracilariaceae (1949). This work presents his descriptions of the critical anatomy of reproductive organs and throws much light on the taxonomy of *Gracilaria* and its related genera. It goes without saying, that the Japanese species of *Gracilaria* hitherto reported fragmentally by various authors such as K. Yendo, K. Okamura, and Y. Yamada were in need of revision. So the present writer started a systematic study of them several years ago under the guidance of Professor J. Tokida, as he believed that taxonomic knowledge of this group of plants is indispensable for any further studies on their ecology or industrial possibilities. Some new data have already been reported in previous papers (1955 & 1956). In the present paper it is proposed to give descriptive accounts of all the species of *Gracilaria* and *Gracilariopsis* occurring in Japan and its neighboring waters. These several years the writer has been doing his best to collect fresh materials from various localities as far as possible, and he has tried to study specimens preserved in liquid except when dried specimens only were available. Anatomical details of various plants were examined with the material thus collected by the writer himself. On the other hand, herbarium specimens made available from various sources were, of course, quite helpful, or in some cases indispensable, for the present systematic studies. The following is a list of the main sources of such specimens.

1. Herbarium of the Faculty of Fisheries, Hokkaido University, containing specimens mostly collected by Professor J. Tokida or under his care from the coasts of Saghalien, Hokkaido, Honsyû, Ryûkyû and Formosa.

2. Collection of Professor Y. Yamada in the Herbarium of the Botanical Institute, Faculty of Science, Hokkaido University; they are noted in the following pages as *Herb. B. H.* (Herbarium of the Botanical Institute, Hokkaido University) together with their number.

3. A comprehensive collection from the Northeast Pacific Coast made by Dr. E. Yale Dawson.

4. Yendo's collection in the Herbarium of the Botanical Institute, Faculty of Science, Tokyo University.

5. Collection from the coast of Honsyû made by Dr. S. Ueda of the Tokyô College of Fisheries.

6. Collection from Shimoda Bay, Shizuoka Prefecture by Mr. M. Chihara.

7. Collection from the coasts of Honsyû and Shikoku by Mr. I. Umezaki.

8. Collection from the coast of Shikoku by Mr. S. Yagi.

9. A small but useful collection made by Mr. K. C. Fan from the coast of Formosa.

In addition to these collections, many other specimens were submitted for examination by many gentlemen including Dr. S. Segawa of the Faculty of Agriculture,

Kyûshû University, Dr. T. Segi of the Faculty of Fisheries, Prefectural University of Mie, Dr. G. W. Lawson of the University College of Ghana, Achimota, Ghana, and Mr. K. Ôshima in Toyama Prefecture. After studying carefully all of these specimens the writer gives in the following pages thorough descriptions based on his own observations for each of fifteen species and one forma of *Gracilaria* and three species of *Gracilariopsis*, including one species new to Japan, *Gracilariopsis rhodotricha* Dawson, one species new to Ryûkyû, *Gracilaria salicornia* (Ag.) Dawson and one species with newly combined name, viz., *Gracilariopsis chorda* (Holm.) Ohmi. *Gracilaria sublittoralis* is described herein for the first time. The identity of *Corallopsis opuntia* and *Gracilaria crassa*, which was already reported by Börgesen (1952) and Dawson (1954, 1954a), is again ascertained positively herein. Antheridia of the following species are reported herein for the first time : *Gracilaria blodgettii*, *G. bursa-pastoris*, and *G. arcuata*. Antheridia of *Gracilaria textorii* were first reported by the writer in 1955. Tetrasporangia of *Gracilaria edulis* and *G. incurvata* and gland-like cells of *G. crassa* and *G. salicornia* are reported herein for the first time.

For the determination of genera and species, the writer has followed Dawson in laying stress on the internal structure of cystocarp, the characters of the male reproductive organ, and on the structure of tetrasporic cortex. In addition, the structure of sterile frond as seen through longitudinal section and of the carpogonial branch was also useful in some cases for the specific distinction.

All the specimens used for the present study, except Yendo's collection in the Herbarium of the Botanical Institute, Faculty of Science, Tokyo University, and Professor Yamada's collection, are now deposited in the Herbarium of the Faculty of Fisheries, Hokkaido University.

In *Gracilaria* and *Gracilariopsis*, there are several species which deserve special consideration from the economic standpoint. One chapter (Chapter IV) will be devoted to such considerations, especially on the resources of *Gracilaria verrucosa* and the agar-agar production from *Gracilaria* in Japan.

Acknowledgements. The writer wishes to take this opportunity to tender thanks to all of those who have aided him in one way or another, during the course of the present study. First of all, the writer will always heartily feel the warmest gratitude to his teacher, Professor J. Tokida, under whose guidance the present work has been carried out. He kindly made available all the specimens he gathered in many years from Saghalien, Hokkaido, Honsyû as well as from Ryûkyû and Formosa, gave permission to make free use of his library and moreover kindly read this manuscript. Cordial thanks are due to Professor Y. Yamada, Faculty of Science, Hokkaido University, for the loan of a number of valuable specimens in the Herbarium of the Botanical Institute and for his constructive criticism of the manuscript; also to Professor Emer. T. Fukushi, Hokkaido University, for the interest he has shown

and the advice he has offered throughout the course of this study. The writer likewisely desires to make acknowledgement of indebtedness to Professor Emer. M. Honda, Tokyo University, through whose kindness it was made possible to examine abundant specimens in Yendo's collection in the Herbarium of the Botanical Institute, Faculty of Science. It is difficult sufficiently to express thankfulness to Dr. E. Yale Dawson who was kind enough to present a comprehensive suite of specimens treated in his "Northeast Pacific Gracilariaceae" and many copies of his publications; they were not only invaluable, but also indispensable for the present study. Furthermore the writer feels very grateful to the late Dr. F. Börgesen of Copenhagen and to Professor W. R. Taylor of Ann Arbor for examining certain specimens sent to them and for returning helpful notes. To Professor T. Tamura, Faculty of Fisheries, Hokkaido University, to Dr. P. C. Silva, University of Illinois, also to Mr. K. Ôgaki, Director of Hokkaido Regional Fisheries Research Laboratory at Yoichi, Hokkaido, the writer is much indebted for their great kindness in granting many facilities for the prosecution of this work. Finally the writer acknowledges his great obligation to all gentlemen who kindly placed rich materials in their possessions at his disposal, among whom the names of the following contributors should be particularly mentioned here: Dr. S. Ueda, Tokyo College of Fisheries; Dr. S. Segawa, Faculty of Agriculture, Kyûshû University; Dr. Y. Okada, Faculty of Fisheries, Nagasaki University; Dr. T. Segi, Faculty of Fisheries, Prefectural University of Mie; Dr. G. W. Lawson, Department of Botany, University College of Ghana, Achimota, Ghana; Mr. I. Umezaki, Department of Fisheries, Faculty of Agriculture, Kyôto University; Mr. T. Masaki, Faculty of Fisheries, Hokkaido University; Mr. M. Chihara, Shimoda Marine Biological Station, Tokyo University of Education; Mr. S. Yagi, Ehime Prefecture; Mr. K. Ôshima, Toyama Prefecture; Mr. M. Durairatnam, Fisheries Research Station of Ceylon; Mr. K. C. Fan, Taiwan Fisheries Research Institute, Formosa, China; Messrs. H. Okesaku and S. Sasaki, Kushiro Station, Hokkaido Regional Fisheries Research Laboratory.

II. KEY TO THE SPECIES OF *GRACILARIA* AND *GRACILARIOPSIS*

I. Cystocarps with a large-celled, usually small-based gonimoblast and nutritive filaments extending into the pericarp

- A. Thalli cylindrical throughout, or sometimes more or less compressed
- 1. Branches constricted at the base
  - a. Branch base more or less constricted; branching highly variable, sparing to abundant; thalli slender .... 1. *Gracilaria verrucosa* (Huds.) Papenfuss (p. 6)

b. Branch base gradually constricted; branching rather sparing, irregular and multifarious; thalli conspicuously robust, at least in lower or middle parts; apices acute .... 2. *Gracilaria gigas* Harv. (p. 10)

c. Branch base abruptly constricted; branching frequent to abundant, alternate or partly secund; thalli robust and turgid .... 3. *Gracilaria blodgettii* Harv. (p. 13)

2. Branches hardly constricted at the base

a. Substance rather stiff and consistent; branching divaricately pinnate; aspect somewhat corymbose; thalli up to 30 cm in length .... 4. *Gracilaria edulis* (Gmel.) Silva (p. 16)

b. Substance soft cartilaginous or membranaceous; branching subdichtomous, provided with short branchlets; aspect somewhat flexuous .... 5. *Gracilaria bursa-pastoris* (Gmel.) Silva (p. 18)

c. Substance succulent; aspect conspicuously corymbose; thalli less than ca 11 cm in lengh ...... 6. *Gracilaria coronopifolia* J. Agardh (p. 20)

d. Substance membranaceous and fleshy; branching extremely divergent, irregularly pinnate, sometimes arcuated above; aspect flexuous or corymbose; thalli 5–10 cm in length .... 7. *Gracilaria arcuata* Zanard. (p. 23)

3. Branches or branchlets articulato-constricted

a. Branchlets articulato-constricted at maturity .... 8. *Gracilaria crassa* Harv. (p. 25)

b. Both branches and branchlets markedly articulato-constricted .... 9. *Gracilaria salicornia* (Ag.) Dawson (p. 27)

B. Thalli distinctly flattened or complanate

1. Thalli provided with abundant marginal spinulose proliferations or denticulate processes

a. Frond broad; margins provided with denticulate processes .... 10. *Gracilaria denticulata* (Kütz.) Weber van Bosse (p. 29)

b. Frond rather narrow, with blunt or ligulate apices; margins heavily crisped .... 11. *Gracilaria purpurascens* (Harv.) J. Ag. (p. 30)

c. Frond broader than the former, with obtuse or truncate apices; margins provided with more abundant spinous processes .... 11 a. *Gracilaria purpurascens* (Harv.) J. Agardh f. *spinulosa* (Okam.) Yamada (p. 32)

2. Thalli provided with entire or proliferous margins which are at least not spinulose

a. Thalli complanate, 1–2.5 cm broad, with entire margins, variegated with spots on the surface . . 12. *Gracilaria punctata* (Okam.) Yamada (p. 35)

b. Thalli complanate, ordinarily with entire margins but without spots on the surface, sometimes channeled or more or less incurved and often

twisted .... 13. *Gracilaria incurvata* Okam. (p. 38)

c. Thalli broader, frequently to abundantly lobed, not incurved, with blunt or ligulate apices, and with or without proliferations .... 14. *Gracilaria textorii* (Suring.) J. Ag. (p. 40)

d. Thalli broadest, sparingly lobed; margins smooth and normally non-proliferous .... 15. *Gracilaria sublittoralis* Yamada et Segawa (p. 44)

II. Cystocarps with a small-celled, broad-based gonimoblast and destitute of nutritive filaments extending into the pericarp

A. Branches swollen in part, vermiform in shape .... 16. *Gracilariopsis vermiculophylla* Ohmi (p. 46)

B. Branches without enlargement or swelling in any part

1. Plant small and slender, up to 20 cm in length, seldom exceeding 1000 μ in diam., frequently branched .... 17. *Gracilariopis rhodotricha* Dawson (p. 47)

2. Plant large, coarse and robust, 60–110 cm in length, 2–3 mm in diam., sparingly branched .... 18. *Gracilariopsis chorda* (Holm.) Ohmi (p. 50)

III. DESCRIPTIONS OF THE SPECIES

1. *Gracilaria verrucosa* (Huds.) Papenfuss

Pl. I, A–D, and Text-figs. 1–2.

Papenfuss, review of the genera of algae described by Stackhouse, 1950, p. 195. *Gracilaria confervoides* (L.) Greville, Alg. Brit., 1830, p. 123; Harvey, Phyc. Brit. I, 1846, pl. 65; J. Agardh, Sp. Alg. II (2), 1852, p. 587; Id., Epicr., 1876, p. 413; Thur. et Born., Étude Phyc., 1878, p. 81, pl. 40; Buffham, Anther., 1893, p. 4, pl. 13, figs. 11–12; De-Toni, Syll, Alg. IV, 1900, p. 431; Killian, Entwick., 1914, p. 254; Okam., Icon. Jap. Alg. IV, 1916, p. 1, pl. 151; Sjöstedt, Florid. Studies, 1926, p. 51; Kylin, Entwick., 1930, p. 55; Dawson, Northeast Pacif. Gracilariaceae, 1949, p. 13, pl. 15, fig. 9. *Fucus confervoides* L., Sp. plant. ed. 2, II, 1763, p. 1629. *Fucus verrucosus* Huds., Flora Anglica, 1762, p. 470.

Japanese name: *Ogo-nori*.

Material examined: *Ohmi* 109–111, ♀; 112–128, ⊕, all from Lake Komuke, Prov. Kitami, Hokkaido, July 1956; *Ohmi* 129–133, ♀; 134–145, ⊕, all from Lake Notoro, Prov. Kitami, July 1956; *Masaki*, Oshoro Bay, Otaru, Hokkaido, July 1956 (*Herb. Ohmi* 146 a-b, ♂, c-g, ♀; 147, ♀; 148 a, ♂, b, sterile, c, ⊕, d, ♀, e, ♂; 149 a-b, ♀, c, ♂, d, ⊕; 150–151, sterile, ⊕).

Fronds arising usually in a fairly great number from a common small fleshy flat disc, composed of vertical cell-rows; the upright cylindrical frond reaches 2 mm

or more, seldom exceeding 1.5 mm in diam., attaining a length of 90 cm in the specimens collected at Lake Notoro, Prov. Kitami, Hokkaido, while most of the specimens collected at Oshoro Bay, Hokkaido, hardly exceeding 20 cm in length; branching alternately and repeatedly on all sides with mostly patent or erect axils, sometimes one-sidedly or quite naked and flagelliform; branches elongated, with longer or shorter internodes, tapering upwards and also perceptibly contracted to their bases, and provided with similarly shaped but shorter branchlets which are loaded with mostly simple, longer or shorter ramuli, ending in blunt apices. The plant varies within a wide range in length, thickness, color and even in ramification; purplish red or sometimes greenish or brownish in color, cartilagenous in substance, and adhering well to paper on drying; frond tissue differentiated into a thin cortex composed of two to three layers of small cortical cells and a thick medullary tissue built up of large (150–250 μ, rarely to 360 μ in diam.), round, isodiametric cells having a wall ca 6 μ thick. The frond sometimes becomes hollow when old. The outermost cortical cells are strongly pigmented, more or less anticlinally elongated, 6–8 $\mu \times$ 10–14 μ in dimensions as viewed in transverse section. The infracortical cells are mostly three-layered, being connected with each other by numerous pits. Transition from inner medulla to outer cortex is abrupt. The young parts of the plant bear numerous hairs. Hairs are ca 5 μ thick, with obtuse apex, suppported by a large elongated hair "base-cell", deciduous, particularly abundant near the frond apex, where they are somewhat thinner, ca 3 μ thick, and their length is variable. Surface jelly substance ca 6 μ thick. Tetrasporangia densely scattered over the greater part of frond, bright red in color, and cruciately divided. In transverse view they are ovoid in shape, up to 40 $\mu \times$ 50 μ, surrounded by unmodified cortical cells, and in surface view roundish in shape. Cystocarps hemispherical, non-rostrate, not constricted at the base, scattered on the whole surface of the frond, often aggregated, 0.9 mm in diam., 0.7 mm in height at maturity as observed in Oshoro specimens, whereas they attain 1.4 mm in diam., 1.0 mm in height in Notoro plant. According to Sjöstedt (1926) and Kylin (1930), the carpogonial branch is two-celled and developed from a primary cortical cell. The writer observed in a specimen from Asano-cho, Hakodate, a structure probably identifiable as the initial of a caropogonial branch (Fig. 2, A–C), which was deeply stained with cotton blue. The pericarp is connected with the gonimoblast by numerous nutritive filaments, which are 15 μ in thickness and ca 150–180 μ in length. Gonimoblast consists of large vacuolated cells. Carpospores are round or ovate in shape, up to 40 μ in diam. Pericarp is ca 100–240 μ thick, consists of one layer of outermost pigmented cells and ca 10 layers of inner hyaline cells arranged anticlinally and radially and connected by pits with each other. Antheridia occur densely on the frond surface in deep depressions, which are round in shape or sometimes oblong along the frond axis as seen in surface view, deep pocket-like in transverse view, bordered by unmodified cortical cells, and packed with small globular antherozoids, ca 3–5 μ in diam. The dimensions of the

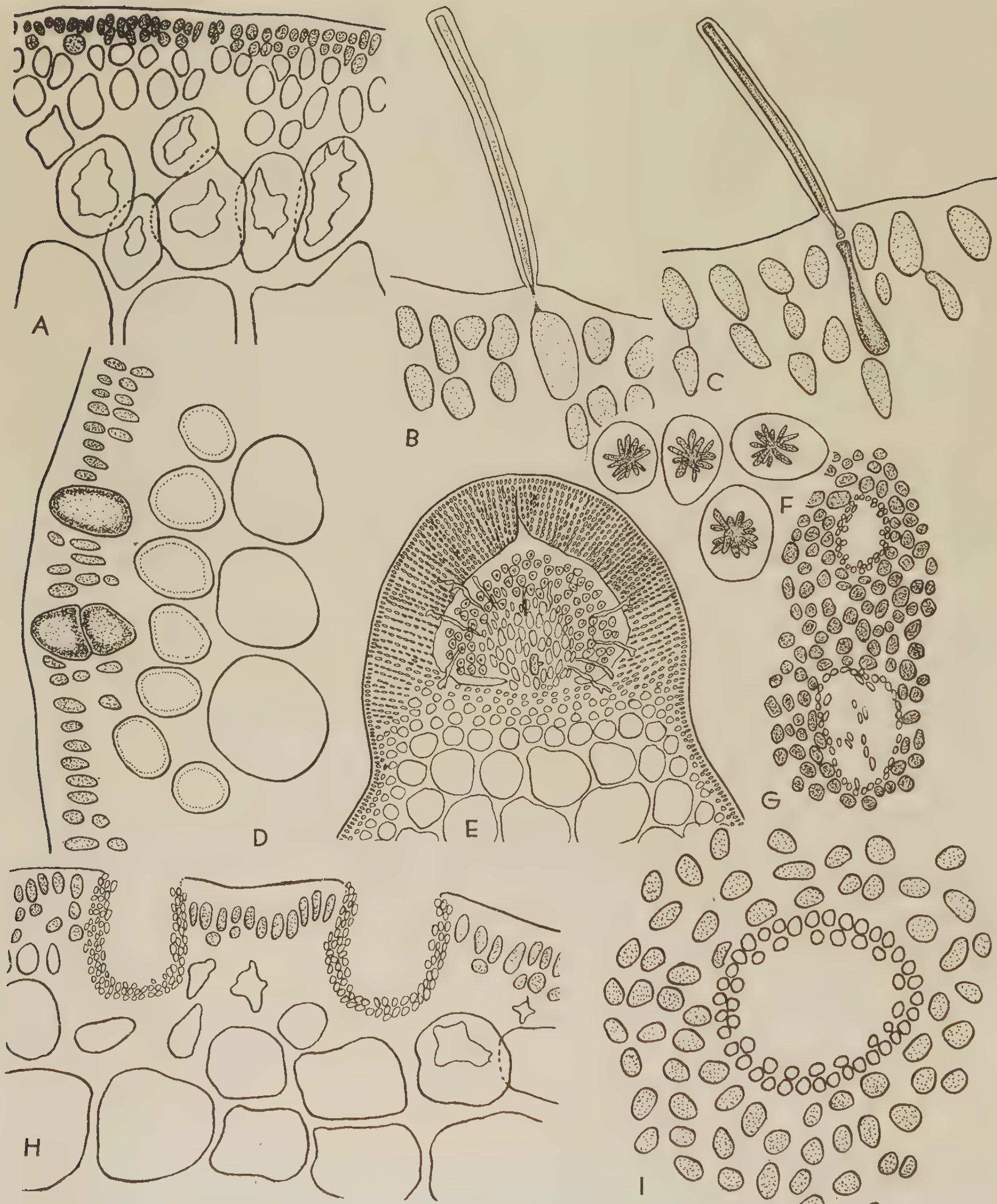


Fig. 1. *Gracilaria verrucosa* (Huds.) Papenfuss. A. Transverse section of a sterile frond from Nanaehama near Hakodate, Aug. 1955. ×284. B-C. Transverse section of a sterile frond to show a hair in the cortex, B from Tôbetsu near Hakodate, May 1955, and C from Oshoro, July 1947. ×514. D. Transverse section of a tetrasporic frond from Oshoro, July 1956. ×284. E. Transverse section of a mature cystocarp; Oshoro, July 1956. ×50. F. Detail of carpospores showing stellate central body; Oshoro, July 1956. ×284. G. Part

of an antheridial frond as seen in surface view, showing openings of elliptical antheridial cavities; Matsushima Bay, Miyagi Pref., June 1953. ×284. H. Transverse section of a part of an antheridial frond, showing the deep, conceptacular antheridial cavities; Oshoro, July 1956. ×284. I. Surface view of an antheridial cavity; Oshoro, July 1956. ×514.

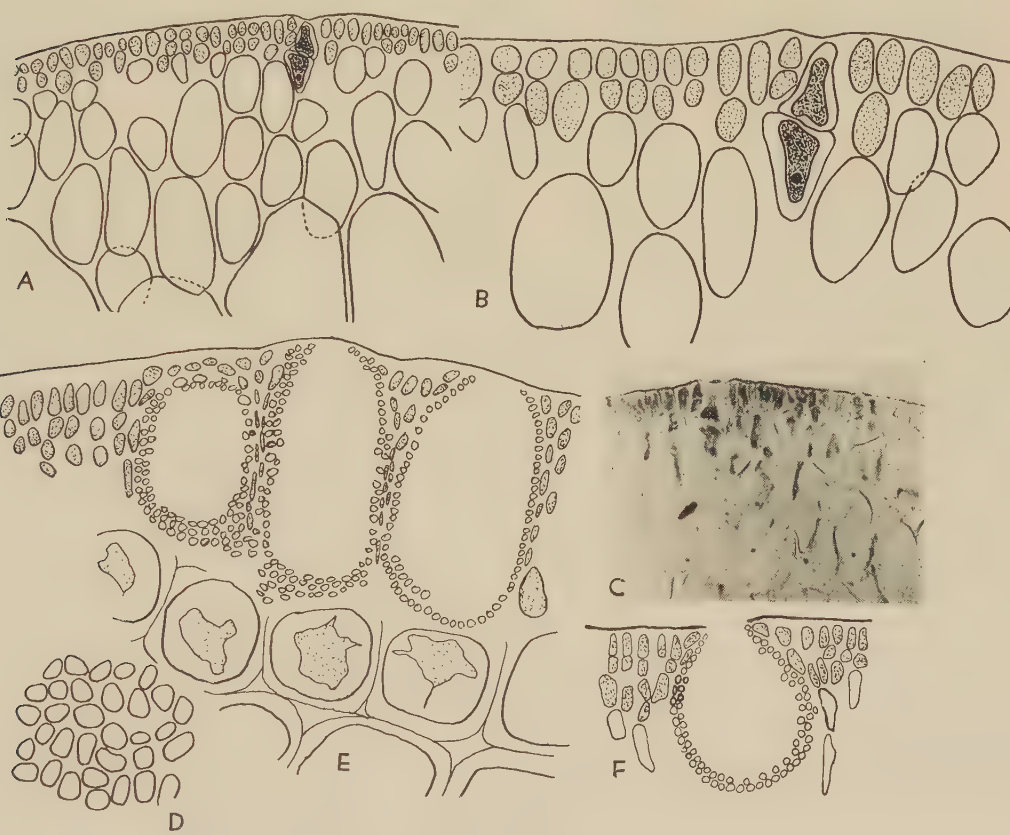


Fig. 2. *Gracilaria verrucosa* (Huds.) Papenfuss. A. Transverse section of a female frond showing the initial of a carpogonial branch; Asano-cho, Hakodate, July 1955. ×284. B. The same as A, more highly magnified. ×514. C. Microphotograph of the same carpogonial branch. ×324. D. Surface view of antherozoids in an antheridial cavity; Tôbetsu near Hakodate, June 1953. ×514. E. Transverse section of a male frond, showing the deep, elliptical antheridial cavities; Tôbetsu near Hakodate, June 1953. ×284. F. Transverse section of a male frond showing a spherical antheridial cavity; Matsushima Bay. Miyagi Pref., June 1953. ×284.

antheridial cavities are shown in Table 1.

This species is cosmopolitic in distribution and is widely spread within the boundaries of this study. It grows mostly near the shore at a depth of less than about one meter or at most two meters. In Lake Notoro it thrives well on shallow

Table 1. Dimensions of antheridial cavities on one and the same frond, measured in transverse section. Specimen collected at Oshoro, Sept. 1947.

No.	Breadth	Depth
1	24 μ	60 μ
2	30	45
3	40	50
4	40	60
5	55	75
6	58	66
7	60	75
8	66	66

sandy or muddy bottom being attached to gravels or shells in the intertidal zone. The plant is perennial. In calm places this alga often attains to a great length as in Lake Akkeshi, Prov. Kushiro, Hokkaido, where it grows luxuriantly, being detached from the substrata and lying loosely on the bottom in quiet water among gregarious growths of *Zostera marina*. When matured bears only tetrasporangia. Besides this detached form, there is also a dwarf form of this alga on the shore of the same lake which grows attached to gravels or shells and bears on maturity not only tetrasporangia but also antheridia and cystocarps. The large detached form is that which fishermen harvest in late autumn and sell to agar-manufacturers. In these past six years the annual yield of this alga in Lake Akkeshi was estimated in the maximum 423,344 *kan* (1 *kan* is equivalent to 3.75 kg) in dry weight in 1952, and in the minimum 64,060 *kan* in 1955.

The marked characters of the present species may be tabulated as follows :

1. Branches attenuated, ending in blunt apices and slightly contracted to the base.
2. Cortex two to three layered, consisting of anticlinally arranged cells.
3. Tetrasporangia scattered over surfaces of frond, surrounded by unmodified cortical cells.
4. Cystocarps hemispherical, unconstricted at the base, nonrostrate, with abundant nutritive filaments connecting the gonimoblast with the pericarp.
5. Antheridial cavities deep pocket-like, bordered by unmodified cortical cells.

2. ***Gracilaria gigas*** Harvey

Pl. I, E–II, A, and Text-fig. 3.

Harvey, Alg. Wright. in Proceed. Amer. Acad. IV, p. 330, n. 24; De-Toni, Phyc. Jap., 1895, p. 28, n. 54; Id., Syll. Alg. IV, 1900, p. 454; Yendo, Kaisan shokubutsu-gaku, 1911, p. 648; Okam., Icon. Jap. Alg. V, 1923, p. 159, pl. 241–242, figs. 1–4; Segawa, On Mar. Alg. Susaki, Prov. Idzu., 1935, p. 81; Okam., Nippon Kaisô-shi, 1936, p. 631.

Japanese name : *Ô-ogonori.*

Material examined : Chihara, Nabeta near Shimoda, Shizuoka Pref., May 1955 (*Herb. Ohmi* 1–11, ♀; 12–16, ⊕); *Yendo* 13, ♀, Tateyama, Chiba Pref., June 1909; *Yendo* 160, ⊕, Seto, Wakayama Pref., Apr. 1896 (*Herb. Tokyo Univ.*); *Yendo* 161, ⊕, Sunosaki, Chiba Pref., Jan. 1899 (*Herb. Tokyo Univ.*); *Sugiyama*, Chiba Pref., Aug. 1906 (*Herb. Yendo* 313, 315, ⊕); *Sugiyama*, Chiba Pref., Aug. 1906 (*Herb.*

Yendo 319, ♀); *Ueda* B-1, ♀, Enoshima, Kanagawa Pref., June 1951; *Tokida* 3-a, ⊕, 3-b, ♀, both from Seto-kanayama, Wakayama Pref., Apr. 1938; *Akiyama*, Misaki, Kanagawa Pref., May 1927 (*Herb. B. H.* 9463, ⊕); *Teramachi*, Wakayama Pref., without date of collection (*Herb. B. H.* 11075, ♀, ⊕); *Teramachi*, Wakayama Pref., without date of collection (*Herb. B. H.* 11076, ♀, ⊕); *Yamada*, Misaki, Kanagawa Pref., May 1937 (*Herb. B. H.* 20074, ⊕); *Inoh*, Seto-kanayama, Wakayama Pref., June 1940 (*Herb. B. H.* 27270, ⊕); *Inoh*, Seto-kanayama, Wakayama Pref., June 1940 (*Herb. B. H.* 27271, ♀).

Frond solitary or caespitose, cylindrical, arising from a scutate disc, reaching the length of 60 cm or more, 2–4 mm in diam., irregularly and sparingly branched at short intervals (mostly 0.5–3 mm in distance) on all sides, or sometimes subsecundly branched with patent and roundish axils, highly fleshy in substance, somewhat translucent light purplish red in color when fresh, but on drying dull red or pale greenish in color and much collapsed and wrinkled, adhering well to paper; branches up to 50 cm in length, narrowing towards the base ordinarily in a gradual but occasionally in an acute manner, constricted at the base, long attenuated to a fine apex, scarcely furnished with branchlets; main axis obscurely traceable; frond tissue consisting of large, colorless thin-walled medullary cells (6–9 μ to 15 μ in thickness), which are roundish in shape as viewed in transverse section, 0.5–0.7 mm in maximum diameter, almost empty in content, often becoming hollow (measuring 1.0 mm in diam.) at the innermost part of old frond; cortex composed of 3–4 layers of small pigmented cortical cells, of which outermost cells are cuboid in shape, somewhat anticlinally disposed, measuring 6–8 μ $\times$ 10 μ in dimensions as viewed in transverse section and $6\mu \times 9\mu$ in surface view; hairs long or stubby in shape, infrequently present; infracortical layer built up of 3–4 layers of periclinally oblong cells, measuring 15–40 $\mu \times$ 45–170 μ in dimensions as observed in longitudinal section, thus an abrupt transition from inner medulla to outer cortex results; in some specimens the infracortical layer is traversed here and there by thin, axially elongated cells, 5–8 μ thick, which run between the above mentioned oblong cells, and bear a resemblance to the filamentous cells in the medulla of Laminariaceous plants, and may probably belong to an endophyte. Tetrasporangia densely scattered over surface of frond except at the extreme base of branches, ovoid to oblong in shape, cruciate, 36–51 $\mu \times$ 60 μ in dimensions in transverse section, closely packed in the slightly-modified cortex of anticlinally elongated cells. Cystocarps hemispherical, up to 1.6 mm in diam., rostrate, scattered on surface of entire frond; gonimoblast composed of large parenchymatous cells, connected with the pericarp by several nutritive filaments; pericarp ca 180 μ in thickness, consisting of 10–15 layers of minute cells, of which the outermost are 5–6 $\mu \times$ 6–12 μ in dimensions and more or less anticlinally elongated, while the inner cells are somewhat compressed in the anticlinal direction; carpospores round or ovoid, 33–51 μ in diam. at maturity, with a conspicuously pigmented stellate central body; antheridia unknown.

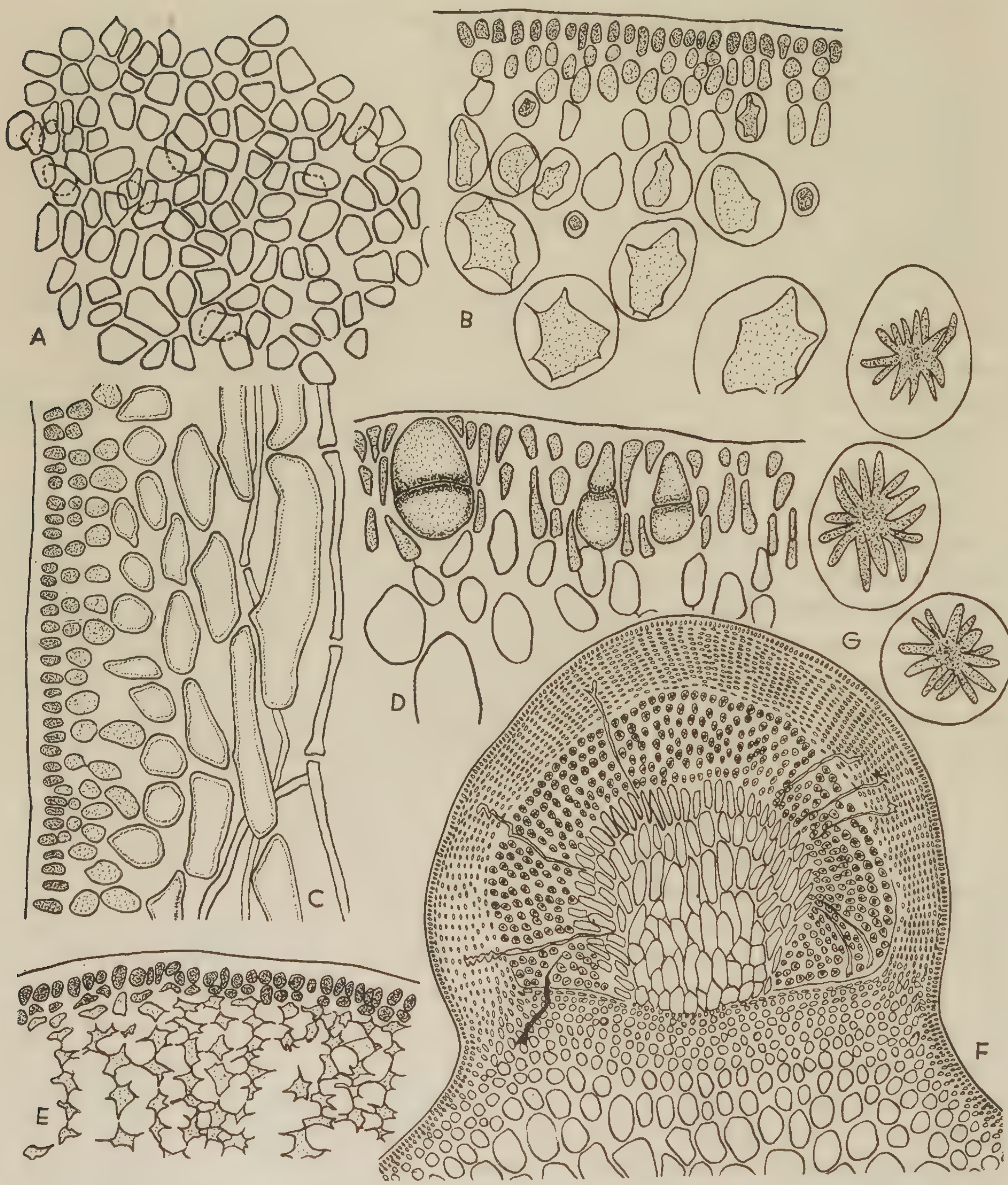


Fig. 3. *Gracilaria gigas* Harv. A. Surface view of a part of a sterile frond, showing arrangement of vegetative cortical cells. ×514. B. Part of a sterile frond in transverse view. ×284. C. Longitudinal section of a sterile frond, showing thin, elongated cells between infracortical cells. ×284. D. Transverse section of a tetrasporic frond. ×284. E. Part of the pericarp of a cystocarp in section. ×284. F. Section of a mature cystocarp. ×50. G. Detail of carpospores showing stellate central body. ×514. (A-G. Plant from Nabeta near Shimoda, Shizuoka Pref., May 1955).

At first sight the present plant has some resemblance in external appearance to *Gracilaria blodgettii* Harvey. However, it differs from the latter in its scarcer ramifications and in having peculiarly constructed infracortical layer. That layer consists in the present species of oblong or axially elongated cells, whereas in *G. blodgettii* it is composed of approximately isodiametric parenchymatous cells. In addition, the pericarpial cells of the present species are compressed in the anticlinal direction with the exception of the outermost antilcinally elongated cells, whilst those of the latter species are all elongated anticlinally. In referring specimens at hand to this species it was possible to compare them with a photograph of Harvey's original specimen taken by Yendo. The paper on which the specimen was mounted is shown to bear a label with hand writing which reads "Herbarium of the U. S. North Pacific Exploring Expedition under Commanders Ringgold and Rodgers, 1853–'56, collected by C. Wright at Shimoda, growing on rock." According to Okamura (1923), "In the frond growing in a calm place after having dropped off the most of branches, the remaining ones, either almost naked or provided with short filiform secondary ramuli, become very much elongated so long as 5 m or even 10 m, having the diameter of 4–5 mm." As to the habitat, Chihara supplies the information by letter that it grows at Nabeta Bay on rocks and boulders on sandy bottom below low tide mark, preferring calm and protected places near the open sea, and particularly luxuriantly at estuarine waters.

3. ***Gracilaria blodgettii*** Harvey

Pl. II, B–III, A, and Text-figs. 4–5.

Harvey, Nereis Bor. Amer. 1853, p. 111; J. Agardh, Epicr., 1876, p. 416; De-Toni, Syll. Alg. IV, 1900, p. 437; Id., *ibid.* VI, 1924, p. 258; Taylor, Mar. Alg. Florida., 1928, p. 151, pl. 23, fig. 9, pl. 33, fig. 6; Weber v. Bosse, Liste alg. Siboga. IV, 1928, p. 430, fig. 174; Okam., Nippon Kaisô-shi, 1936, p. 629.

Japanese name: *Kubire-ogonori* (n. n).

Material examined: *Chihara*, Susaki near Shimoda, Shizuoka Pref., July 1955 (*Herb. Ohmi* 68–69, ♀; 70–71, ♂; 72 a, ⊕, 72 b, ♂; 73, ⊕); *Chihara* ,Susaki, March–June 1955 (*Herb. Ohmi* 75–78, 82, ♀; 79–80, ♂; 81, ⊕; 82–84, ♀; 85, ⊕); *Fan* 1856 a, ♂, b, ⊕, ♂, c, ♂, d-e, ⊕, f, ♀, g-h, ♂, i, ⊕, j, ♂, k, ⊕, l, ♀, m-o, ⊕, Tung-shih, Chia-I Pref., Formosa, June 1953.

Frond caespitose, robust and turgid, mostly 10–30 cm in length, cylindrical, reaching a thickness of 3.5 mm, arising from a small disc; percurrent axis obscure or sometimes traceable; branches abundantly spread out on all sides, alternately or secundly, 3–16 cm in length, abruptly constricted at the base; frond consisting of three kinds of tissues; medulla composed of large parenchymatous isodiametric or polygonal cells which are 0.5–0.6 mm, rarely up to 0.7 mm in diam. and with a thin wall, 2–5 μ in thickness, merging rather abruptly into the subcortex of one to two layers of ovoidal

cells, 18–30 μ in diam., and essentially two-layered cortex of small, pigmented, more or less anticlinally arranged cells, which are roundish square in shape, 4–9 $\mu \times$ 9–12 μ in dimensions and with surface jelly ca 9 μ thick. Tetrasporangia densely scattered

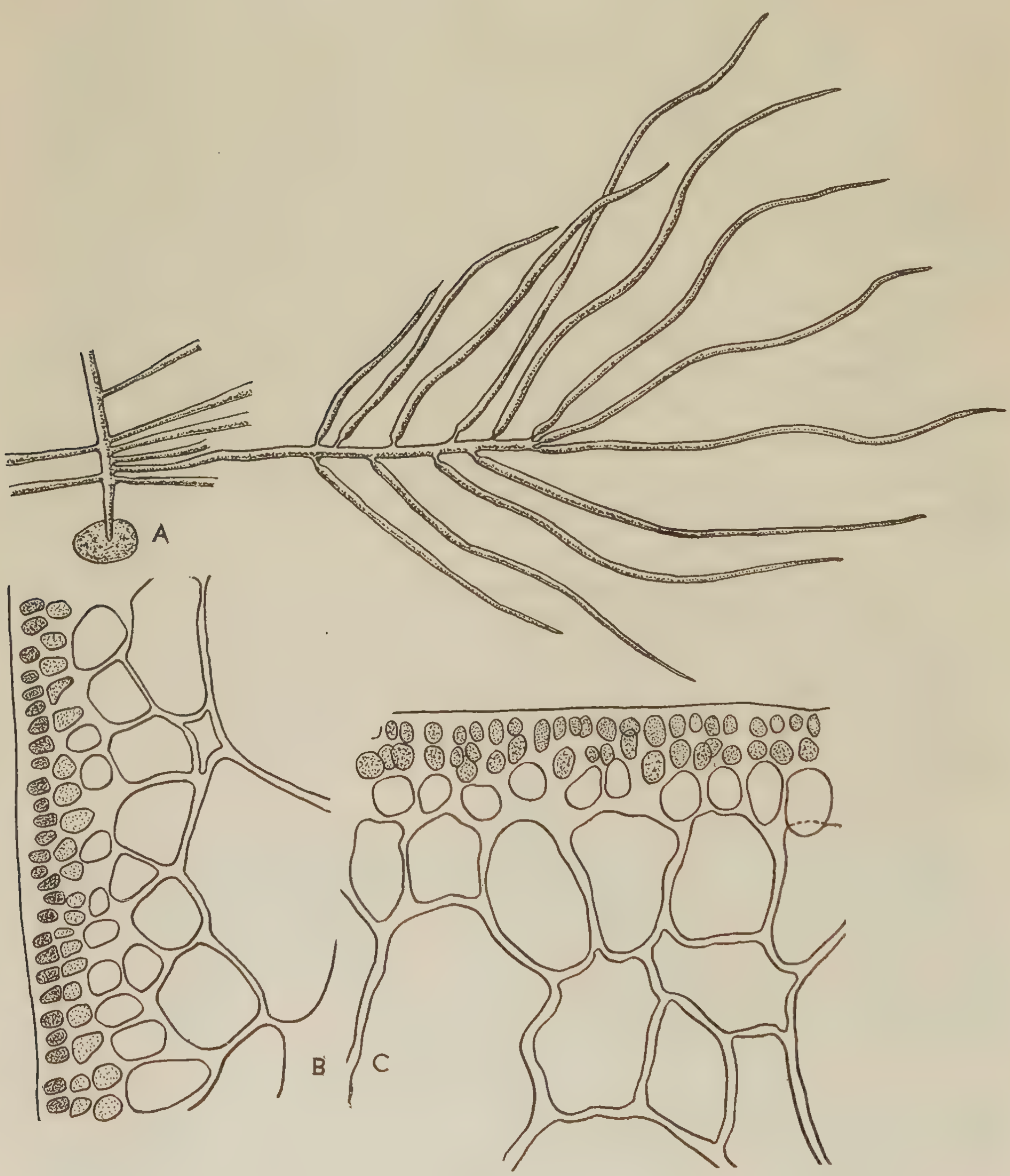


Fig. 4. *Gracilaria blodgettii* Harv. A. Detail of branching in the terminal portion of a frond. × 2/3. B. Longitudinal section of a sterile frond. ×284. C. Transverse section of a sterile frond. ×284. (A-C. Plant from Susaki near Shimoda, Shizuoka Pref., July 1955).

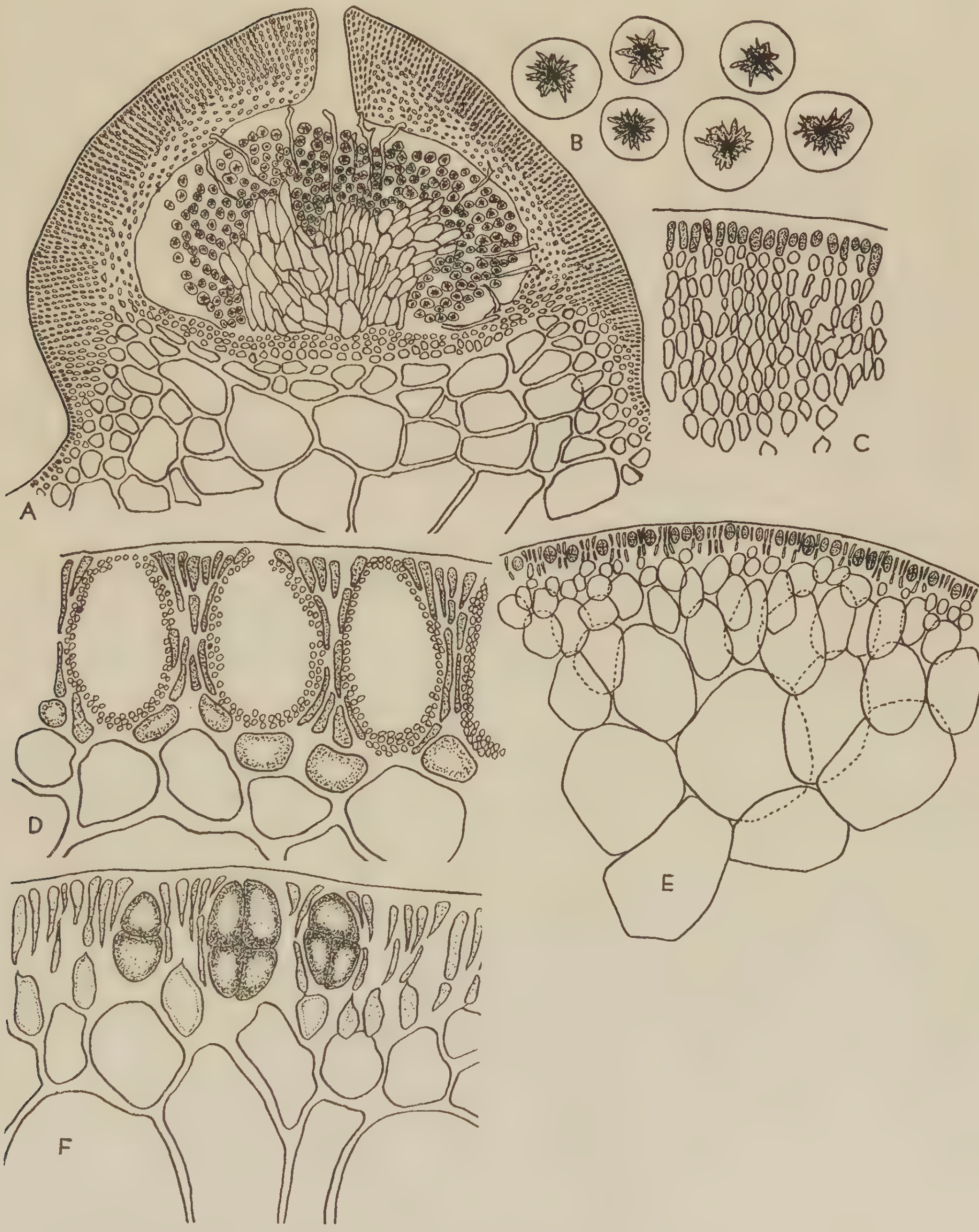


Fig. 5. *Gracilaria blodgettii* Harv. A. Section of a mature cystocarp. ×50. B. Detail of carpospores showing stellate central body. ×284. C. Part of the pericarp of a cystocarp to show the radial arrangement of cells. ×284. D. Part of an antheridial frond in transverse section, showing deep conceptacular cavities. ×284. E. Transverse section of a tetrasporic frond. ×50. F. The same section, more highly magnified. ×284. (A-F. Plant from Susaki near Shimoda, Shizuoka Pref., July 1955).

over the greater part of frond, ovate to oblong in shape as seen in transverse section of the frond, 15 $\mu\times 36\ \mu$ to 54 $\mu\times 66\ \mu$ in dimensions at maturity, bordered by conspicuously anticlinally modified cortical cells, cruciately divided, rose-red in color. Cystocarps prominently protruding, up to 1.7 mm in diam., globose, subrostrate, slightly constricted at base, with a large, somewhat lobed gonimoblast of large parenchymatous cells, arising from a large fusion cell, ca 75 $\mu\times 120\ \mu$ in dimensions, with a wall 4–5 μ in thickness, and connected to the pericarp by a number of nutritive filaments, 170–260 μ in thickness; carpospores round or ovoid in shape, 20–30μ rarely up to 54μ in diam. at maturity, containing a conspicuous stellate central body. Antheridia borne abundantly all over the surface of frond, in deep, ovoid, regularly and closely spaced cavities, up to 36–70$\mu\times$45–120μ in dimensions, surrounded by modified cortical cells. They have a rather small opening. The specimens from Susaki were found to bear tetrasporangia and cystocarps in March, and tetrasporangia, antheridia and cystocarps in the months from April to June. Among the specimens from Formosa an interesting frond was observed which was bearing both antheridial cavities and tetrasporangia, each in separate groups. *Ulva pertusa* Kjellm. and *Bryopsis* sp. are often found growing upon the branches. When fresh, the plant is succulent cartilaginous in substance and translucent deep rosy red, often chestnut or rusty-brown or aeruginose as observed in Formosan plants. Upon drying it changes into dull red or greenish red in color, and becomes much collapsed, adhering rather well to paper.

The present species exhibits a good resemblance to *Gracilaria cylindrica* Börgesen, but it differs from the latter in having customarily filiform branch-apex, and more gradually narrowed branch bases when old, and in its rather indistinct primary axis and more abundant ramification. Judging from the description given by De-Toni (1900) and from description and photograph by Taylor (1928), the specimens at hand are somewhat larger and thicker in external size than their materials. However, in the internal structure no line of demarcation between them can be found by the writer. So it seems that the specimens may be referable to the present species, which is known to be extremely variable in external morphology. As regards the habitat of the Formosan plant, its collector states: "On the shells of oyster or washed ashore, of which substratum is muddy."

4. *Gracilaria edulis* (Gmelin) Silva

Pl. III, B, and Text-fig. 6

Silva, A review of nomenclatural conservation in the algae from the point of view of the type method, 1952, p. 293. *Gracilaria lichenoides* (L.) Harv. in Lond. Jour. III, p. 445; J. Ag., Sp. Alg. II, 1852, p. 558; Id., Epicr., 1876, p. 412; De-Toni, Syll. Alg. IV, 1900, p. 430; Okam., Icon. Jap. Alg. VI, 1931, p. 39, pl. 271, figs. 1–5; Id., Nippon Kaisô-shi, 1936, p. 631. *Fucus edulis* Gmel., Hist. Fuc., 1768, p. 113.

Japanese name: *Kata-ogonori.*

Material examined: *Okada* (without number and date of collection), ⊕, Ryûkyû; *Urabe*, Ariake Bay, Aug. 1909 (*Herb. Yendo* 426, ⊕).

Frond filiform, cylindrical, 2.5 mm in diam., up. to 30 cm in length, with a flexuous aspect in habit, gradually attenuating upwards to a sharp apex, repeatedly branched in a divaricate manner; main axis elongated, hardly traceable, provided with subdichotomous branches slightly or not constricted at the base and standing with a patent axil; general outline of branches somewhat corymbose; frond in transverse section consisting of a large-celled medulla bordered by two layers of much smaller cortical cells; medulla composed of 4–5 layers of large roundish cells ca 500 μ in the greatest diam., possessing a wall 6–15 μ thick; cortical cells cuboid, 6 $\mu \times 10$ μ in demensions; transition from medulla to cortex strikingly abrupt; brownish red in color, soft cartilaginous in substance, adhering rather well to paper on drying.

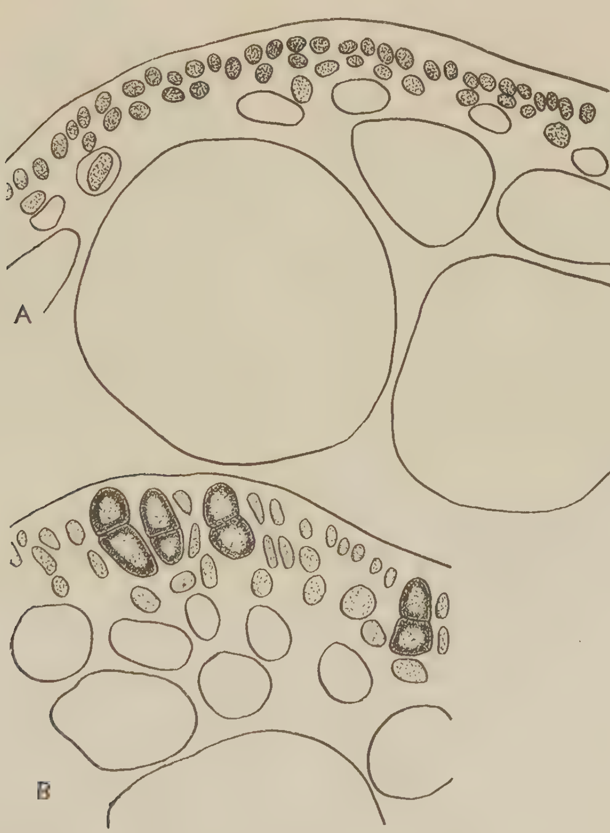


Fig. 6. *Gracilaria edulis* (Gmel.) Silva. A. Transverse section of a sterile frond. ×284. B. Transverse section of a tetrasporic frond. ×284. (A-B. plant from Ariake Bay, Kyûshû, Aug. 1909).

Tetrasporangia ovoid or oblong, 18–36 $\mu\times$45–50 μ in dimensions, cruciate, densely scattered on the surface of frond, surrounded by more or less modified cortical cells. Antheridia and cystocarps absent in the material examined. Though the writer was not able to observe them in the material collected within the area under discussion it, fortunately, was possible to examine the cystocarps as well as tetrasporangia in the so-called Ceylon moss, *Gracilaria edulis*, through the kindness of Mr. M. Durairatnam of the Fisheries Research Station of Ceylon. His plant, collected by himself at Kalpitiya, Ceylon, in March 1956, coincides with the present specimens in external and internal characters. The cystocarp of his plant is provided with abundant nutritive filaments connecting the gonimoblast to the pericarp, and thus it is confirmed that this species is a *Gracilaria*. Judging from the description by Okamura and from the two photos of *Gracilaria lichenoides* from Java in J. Agardh's Herbarium (nos. 29051–29052) taken by Yendo, the placement of the specimens at hand under the present species is believed reasonable.

5. ***Gracilaria bursa-pastoris*** (Gmel.) Silva

Pl. III, C–IV, B, and Text-fig. 7.

Silva, A review of nomenclatural conservation in the algae from the point of view of the type method, 1952, p. 265, *Gracilaria compressa* (C. Ag.) Grev., Alg. Brit., 1830, p. 125; Harv., Phyc. Brit. II, 1849, tab. 205; J. Ag., Sp. Alg. II, 1852, p. 593; Id., Epicr., 1876, p. 417; De-Toni, Syll, Alg. IV, 1900, p. 438; Yendo, Kaisan Shokubutsu-gaku, 1911, p. 643, f. 183; Okam., Nippon Sôrui mei-i (2nd ed.), 1916, p. 43; Börgesen, Mar. Alg. Danish W. Ind., 1920, p. 374; Okam., Icon. Jap. Alg. V, 1927, p. 160, pl. 242, figs. 5–10; Taylor, Mar. Alg. Florida, 1928, p. 152, pl. 33, fig. 1; Okam., Nippon Kaisô-shi, 1936, p. 630. *Fucus bursa-pastoris* Gmel., Hist. Fuc., 1768, p. 121, pl. 8, fig. 3.

Japanese name: *Shira-mo.*

Material examined: *Yendo* 312, as *Gracilaria secundata* Yendo (nomen nudum), ⊕, Misaki, Kanagawa Pref., Aug. 1906; *Ohmi* 110, sterile, Himi, Toyama Pref., May 1953; *Ueda*, Akitani, Kanagawa Pref., May 1951 (*Herb. Ohmi*, sterile); *Yendo* 314, 316, sterile, Chiba Pref., Aug. 1906; *Obara* 29, sterile, Sado, Niigata Pref., Dec. 1909; *Umezaki*, Shirahama, Wakayama Pref., May 1951 (*Herb. Ohmi* 112–114, 116, ⊕); *Nakamura* 136, ⊕, Izumo-zaki, Shimane Pref., Aug. 1915; *Umezaki*, Shirahama, Wakayama Pref., March 1952 (*Herb. Ohmi* 115, ⊕); *Umezaki*, Usa, Kôchi Pref., June 1954 (*Herb. Ohmi* 117, ⊕); *Urabe* 31, ⊕, Kuchinotsu, Nagasaki Pref., Aug. 1909; *Yendo* 322, coexist. ⊕, ♂, Chiba Pref., Aug. 1906; *Ohmi* 118, ♂, Himi, Toyama Pref., June 1953; *Umezaki*, Usa, Kôchi Pref., June 1954 (*Herb. Ohmi* 119, ♂); *Nakamura* 135, 1–2, ♀, ⊕, Izumo-zaki, Shimane Pref., Aug. 1915; *Umezaki*, Usa, Kôchi Pref., June 1954 (*Herb. Ohmi* 120, ♀); *Umezaki*, Shirahama, Wakayama Pref., May 1951

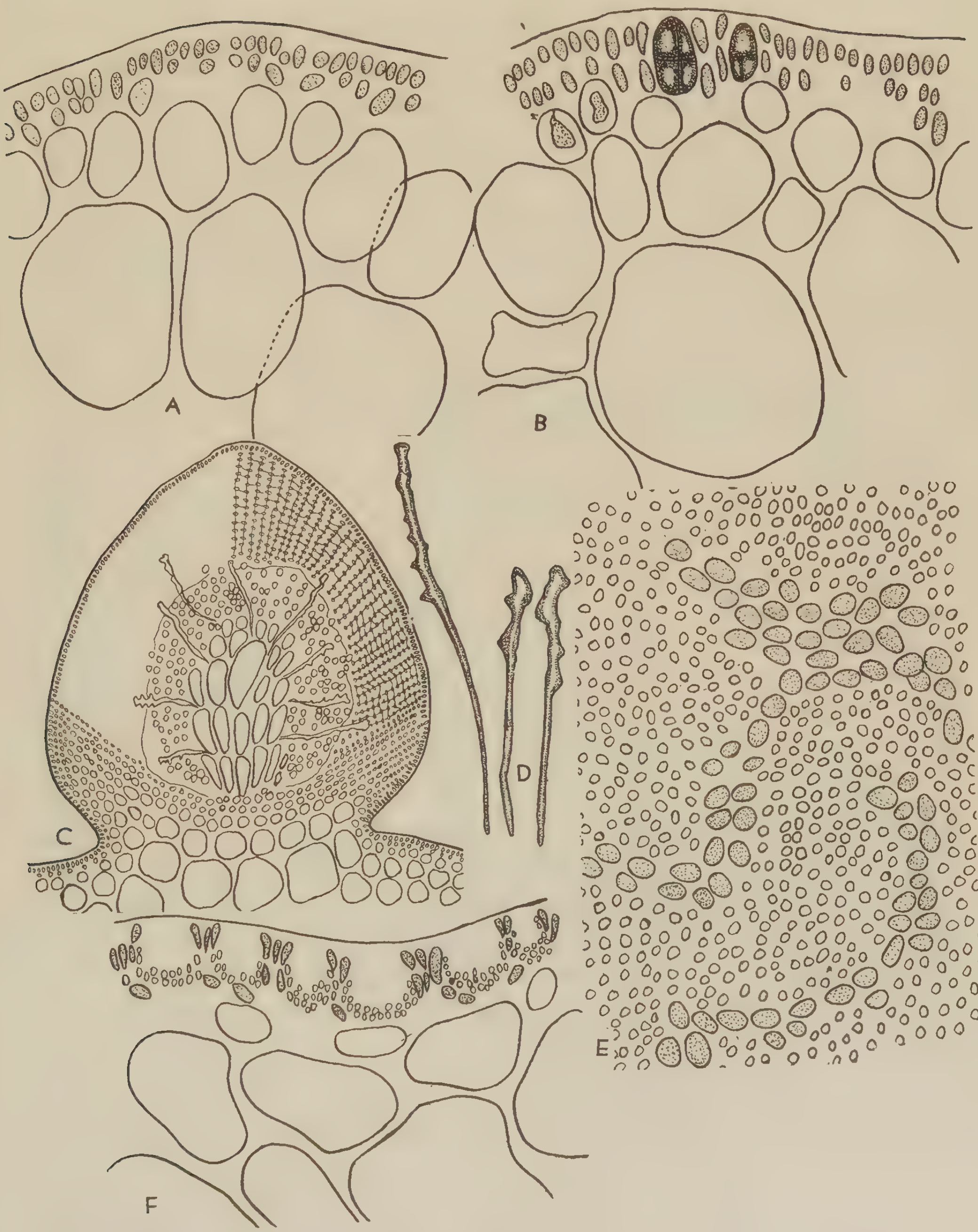


Fig. 7. *Gracilaria bursa-pastoris* (Gmel.) Silva. A. Transverse section of a sterile frond. ×284. B. Transverse section of a tetrasporic frond. ×284. C. Mature cystocarp in section. ×50. D. Detail of three nutritive filaments. ×284. E. Surface view of a part of an antheridial frond. ×514. F. The same antheridial frond in transverse section, showing cup-like antheridial cavities. ×284. (A-D. Plant from Izumozaki, Shimane Pref., Aug. 1915. E-F. Plant from Himi, Toyama Pref., June 1953).

(*Herb. Ohmi* 121, ♀); *Saito* K-3, sterile, Kodomari near Nou, Niigata Pref., Oct. 1954.

Frond erect, caespitose, terete, 15–30 cm high, 2–3.5 mm thick, repeatedly pinnately branched; branches elongated, subdichotomously and usually divaricately branched, somewhat flexuous, arising alternately or subsecundly with patent and rounded axils from unconstricted insertions, often with long intervals below and with short ones above, tapering to a fine apex, provided with short ramuli; frond in transverse section consisting of large thin-walled (3–5 μ thick), roundish, nearly empty medullary cells covered by a cortex composed of two layers of smaller pigmented cells; medullary cells 6–7 layered, 200–600 μ in diam., largest in the central portion and diminishing in diameter outwardly; cortical cells cuboid or elongated, 6 μ×6 μ to 6 μ× 20 μ in dimensions, anticlinally arranged; surface jelly ca 6 μ thick; dark or purplish red to brownish in color, soft cartilaginous or membranous in substance, adhering firmly to paper on drying. Tetrasporangia densely scattered over entire surface of frond, ovoid, up to 33 μ×50 μ in dimensions at maturity, cruciate, surrounded by somewhat modified cortical cells. Cystocarps prominent, conical in shape, constricted at the base, up to 2 mm in diam., 1.7 mm high, non-rostrate; gonimoblast more or less lobulated, composed of extremely vacuolate, elongated cells up to 105 μ×170 μ in dimensions, connnected to the pericarp by numerous nutritive filaments 5 μ thick and 150–240 μ long; pericarp thick, ca 225 μ in thickness, consisting of 10–17 layers of cells, of which the outermost layer cells are pigmented and anticlinally erect, whereas inner layer cells are colorless, connected radially and periclinally with each other by means of distinct connecting filaments. Antheridia borne in the bottom of rather shallow cup or saucer-like cavities, 18–30 μ deep, 30–50 μ broad, at first separated by modified cortical cells, but later becoming confluent.

The present species is characterized by its divaricate aspect, broad insertions of the branches with finely tapering apices and in having conical cystocarps constricted at the base, and shallow cup-like antheridial cavities often more or less confluent. A specimen from Chiba Prefecture (*Yendo* 332) was found to bear both tetrasporangia and antheridial cavities scattered side by side on the frond surface.

As to the habitat of this plant, it is stated by several authors to grow on rocks and stones in calm places near the open sea.

6. ***Gracilaria coronopifolia*** J. Agradh

Pl. IV, C–D, and Text-figs. 8–9.

J. Agardh, Sp. Alg. II, 1852, p. 592; Id., Epicr., 1876, p. 414. *Gracilaria filiformis* Harvey et Bailey in Proceed. Boston Natur. Hist. Soc. 3, p. 372; De-Toni, Syll. Alg. IV, 1900, p. 434; Okam., Nippon Sôrui mei-i (lst ed.), 1902. p. 37; Yamada, Notes on Some Jap. Alg. IX, 1941, p. 202, pl. 45, fig. 8; Abbot, Brackish-water alg. fr. Hawaiian Isl., 1947, p. 206; Dawson, Stud. Northeast Pacif. Gracilariaceae,

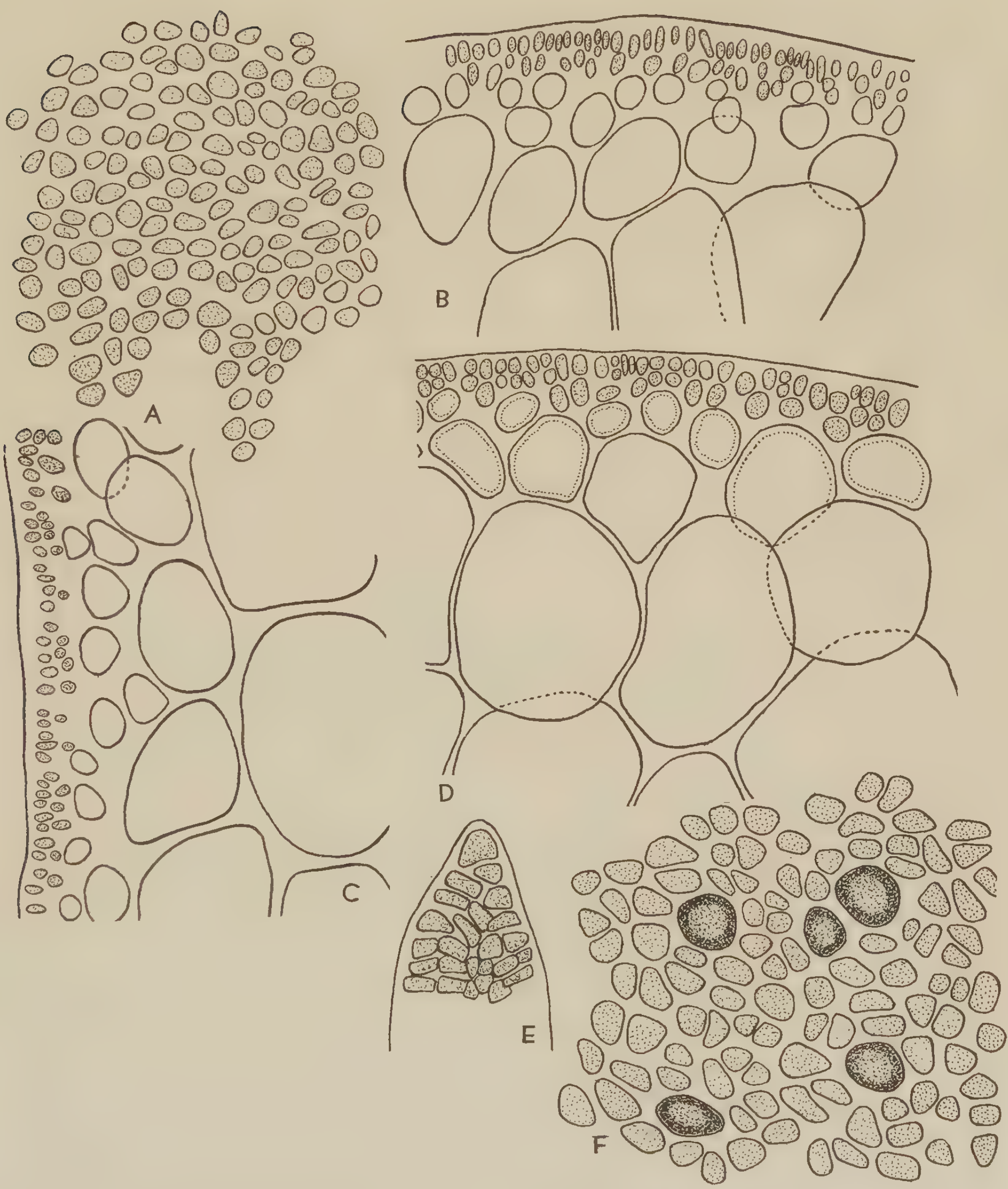


Fig. 8. *Gracilaria coronopifolia* J. Ag. A. Surface view of a part of a sterile frond. ×284. B. Transverse section of a sterile frond. ×284. C. The same sterile frond in longitudinal section. ×284. D. Transverse view of a sterile frond. ×284. E. Apical portion of a branch in surface view showing the single apical cell. ×514. F. Surface view of a part of tetrasporic frond. ×514. (A-C. Plant from Garanbi, Formosa, Apr. 1934. D-F. Plant from Rukyusho, Formosa, March 1952).

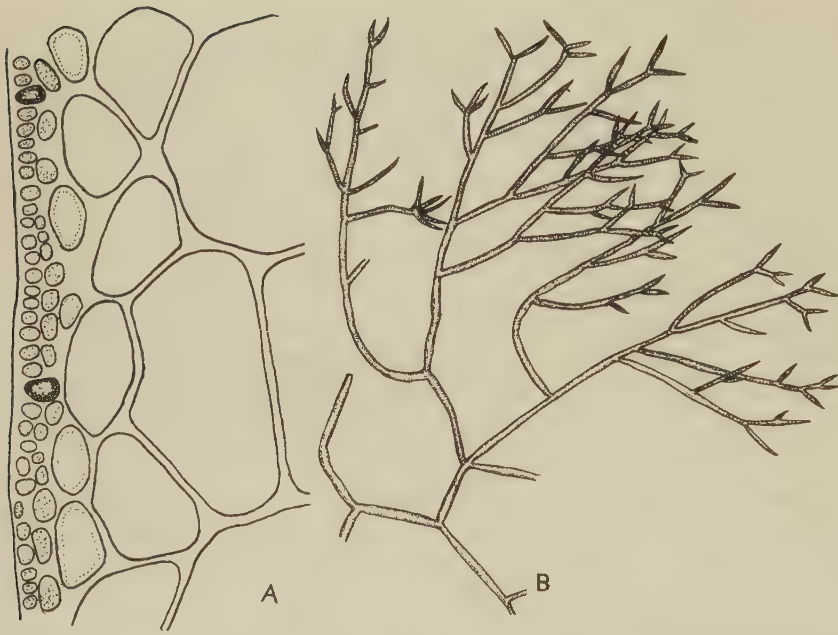


Fig. 9. *Gracilaria coronopifolia* J. Ag. A. Longitudinal section of a plant bearing very young tetrasporangia. ×284. B. Habit of a tetrasporic plant. ×4/5. (A-B. Plant from Rukyusho, Formosa, March 1952).

1949, p. 22, pl. 24, figs. 2–5.

Japanese name: *Mosa-ogonori*.

Material examined: *Yamada*, Garanbi, Formosa, Apr. 1934 (*Herb. B. H.* 21742 a, sterile, b, young ⊕; 21743 a, b, young ⊕; 21744 a, b, sterile, c, young ⊕; 21745 a, b, c, young ⊕); *Tokida* 10 a, b, sterile, Garanbi, Fomosa, May 1938; *Fan*, Rukyusho, Formosa, March 1952 (*Herb. Ohmi* 160).

Frond cylindrical, 7–11 cm long, seldom exceeding 1.5 mm in diam., sometimes arising in large number from a common small disc, dark red to purplish red in color, succulent in substance, becoming cartilaginous and adhering rather well to paper upon drying; branching frequent, particularly more often and densely at upper parts, subdichotomous, sometimes secund, with wide, rounded angle with a rather long internode up to 15 cm long below, but with a shorter one above; branches corymbose, occasionally arcuated at upper parts, ending in bifurcate apices; branchlets occurring mostly near the top of branches, very short and spinous; frond in transverse section consisting of a large medullary tissue of colorless rounded cells, up to 150–250 μ in diam. with walls 6–8 μ thick, surrounded by a narrow, infracortical layer of two-layered cells and two to three layers of smaller cortical cells, pigmented, cuboid, antilcinally arranged, minute, 3–5 $\mu \times$ 5–12 μ in dimensions; transition from

medulla to cortex extremely abrupt; hairs sparsely present; tetrasporangia oblong in surface view, $10\mu \times 15\mu$ to $12\mu \times 18\mu$ in dimensions, ovoid in sectional view, anticlinally arranged, $10\mu \times 18\mu$ to $12\mu \times 20\mu$ in dimensions, scattered over surface of almost entire frond, embedded in the cortex, surrounded by anticlinal rows of 2–3 unmodified cortical cells.

External appearance of the present species is so peculiar that one can easily tell the species from others by its corymbose habit. The cortical cells surrounding the tetrasporangia are unmodified, as described above, but it should be noted here that the sporangia observed were all very young.

7. ***Gracilaria arcuata*** Zanard.

Pl. V, A–C, and Text-fig. 10.

Zanard,. Plant. mar. Rubri enum., p. 265, n. 82, t. 5, f. 2; De-Toni, Syll. Alg. IV, 1900, p. 439; Id., *ibid.* VI, 1924, p. 252; Okam., Icon. Jap. Alg. VI, 1931, p. 40, pl. 272; Id., Nippon Kaisô-shi, 1936, p. 632; Börg., Some Mar. Alg. fr. Mauritius. III (2), 1943, p. 69, f, 35.

Japanese name: *Yumigata-ogonori.*

Material examined: *Yamada*, Kashiwajima, Kôchi Pref., Aug. 1925 (*Herb. B. H.* 8176–8185, ⊕); *Yamada & Tanaka*, Kashiwajima, Kôchi Pref., Aug. 1941 (*Herb. B. H.* 22213, ⊕); *Tanaka*, Suzaki, Kôchi Pref., July 1941 (*Herb. B. H.* 22221, ⊕); *Tanaka*, Kashiwajima, Kôchi Pref., July 1941 (*Herb. B. H.* 22240, ⊕, ♂); *Tanaka*, Kashiwajima, Kôchi Pref., July 1941 (*Herb. B. H.* 22241, ⊕); *Tanaka*, Kashiwajima, Kôchi Pref., July 1941 (*Herb. B. H.* 22248, ♀).

Frond cylindrical, thick and solid, 5–10 cm in length, up to 3 mm or rarely more in diam. when reimmersed in water, arising from a small disc, brownish red or deep purplish in color, often turning into blackish on drying, membranaceous, fleshy in substance, and with a smooth surface while fresh, but collapsed and longitudinally rugose, not adhering firmly to paper, when dried; branching irregularly pinnate, rather distant below with a patent rounded axil and with short intervals above with a narrow axil; branches unconstricted at the base, extremely divergent, flexous or corymbose in general outline, sometimes arcuated upwards, ending in sharp acute apices, provided with secund branches or branchlets mostly on the outer side of the curved portions; Frond in transverse section consisting of a medulla of large thin-walled (5–8μ in thickness) cells arranged in 5–6 layers, roundish in shape, 150-350μ in diam., and an infracortex of 1–2 layered cells, roundish in shape, 30–45μ in diam., filled richly with floridean starch grains, bounded by a cortex of small globular pigmented cells mostly two-layered, of which the outermost cells are roundish or slightly oblong in shape, $4\mu \times 10\mu$ in dimensions, with surface jelly ca 10–15μ thick. Tetrasporangia densely scattered over almost entire surface of frond, round in shape

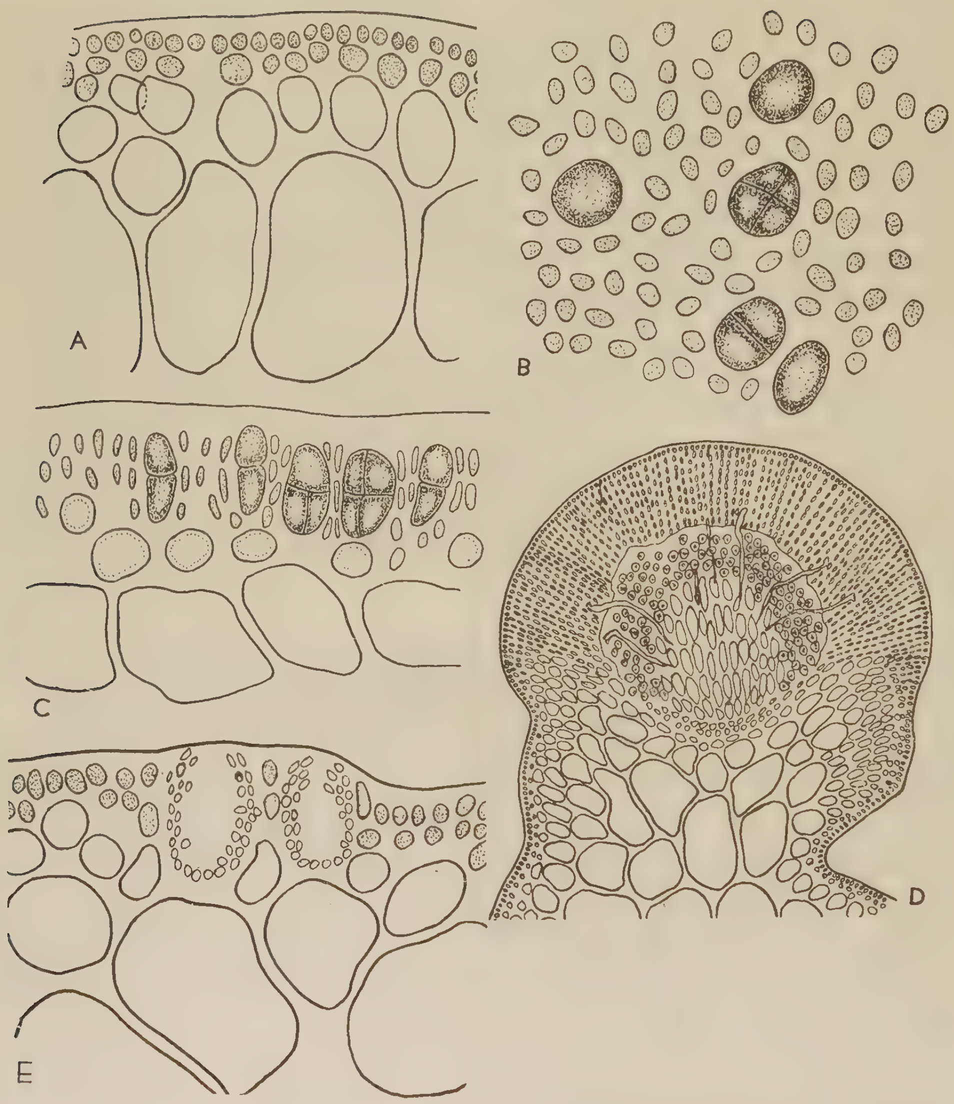


Fig. 10. *Gracilaria arcuata* Zanard. A. Transverse section of a sterile frond. ×284. B. Surface view of a part of a tetrasporic frond. ×514. C. The same tetrasporic frond in transverse section. ×284. D. Section of a mature cystocarp. ×50. E. Transverse section of an antheridial frond. ×284. (A-C. Plant from Kashiwajima, Kôchi Pref., Aug. 1941. D-E. Plant from the same locality, July 1941).

in surface veiw, ovoid or oblong in transverse section, up to 24 $\mu \times 45$ μ in dimensions, surrounded by somewhat anticlinally elongated cortical cells, cruciately divided. Cystocarps globoid prominently protruding, non-rostrate, up to 1.2 mm in diam., 1 mm

in height, constricted at the base; gonimoblast simple, not lobulated, small-based, composed of extremely vacuolate elongated cells; pericarp ca 250 μ in thickness, connected to the gonimoblast by a number of nutritive filaments 3–6 μ in thickness, 150–270 μ in length; carpospores round or ovoid, 24–30 μ in diam. at maturity, with a conspicous pigmented body in the center. Antheridia in roundish sori in surface view, borne in deep pocket-like cavities up to 45 μ in breadth, 60 μ in depth as seen in transverse section, separated by slightly modified cortical cells.

8. ***Gracilaria crassa*** Harvey

Pl. V, D–E, and Text-fig. 11.

Harvey, Alg. Ceylon exsic., no. 29; J. Agardh, Epicr., 1876, p. 417; De-Toni, Syll. Alg. IV, 1900, p. 439; Weber van Bosse, Liste des Alg. du Siboga IV, 1928, p. 431; Yamada, Notes on Some Jap. Alg. V, 1933, p. 281, pl. 13, fig. 1; Okam., Nippon Kaisô-shi, 1936, p. 632; Börg., Some Mar. Alg. fr. Ceylon, 1936, p. 86, fig. 8; Id., Some Mar. Alg. fr. Mauritius IV, 1952, p. 33; Dawson, Mar. pl. vicinity Inst. Océanogr. Nha Trang, Viêt Nam, 1954, p. 438. *Corallopsis opuntia* J. Agardh, Epicr., 1876, p. 409; De-Toni, Syll. Alg. IV, 1900, p. 459; Yamada, Notes on Some Jap. Alg. V, 1933, p. 280; Okam., Icon., Jap. Alg. VII, 1933, p. 13, pl. 308, figs. 6–11; Id., Nippon Kaisô-shi, 1936, p. 634; Börg., Some Mar. Alg. fr. Mauritius. III (2), 1943, p. 67; Id., *ibid.* Additions II, 1950, p. 24.

Japanese name : *Taiwan-ogonori* or *Fushikurenori*.

Material examined : *Tokida* 22, ⊕, Naha, Ryûkyû, June 1938; *Fan* 1108, sterile, Shinko, Taitung Pref., Formosa, Apr. 1951.

Frond cylindrical, caespitose, often attaching to corallinous algae or mollusc shells, up to 8 cm in length, ca 2.5 mm in diam., constricted below when old, repeatedly branched irregularly and divaricately to trichotomously; purplish or dark greenish in color, carnose or soft cartilaginous in substance, adhering firmly to paper on drying; branches, when the plant matured, markedly articulato-constricted, with ovate, subcuneate, oblong or subpyriform articulations, 1.5-5 mm broad, 2–4 times as long as broad.

The above description is a modification of what Okamura gave in 1933 to *Corallopsis opuntia* J. Agardh.

The following description is based on the writer's own observations of the material at hand.

Frond in transverse section with a cortex ordinarily consisting of two layers of pigmented small cells, of which the outermost ones more or less anticlinally disposed, 4 $\mu \times$ 6–12 μ in dimensions, with surface jelly ca 15 μ thick. The cortex in surface view is always provided with abundant large gland-like cells; they scatter over the surface of frond, mostly roundish or sometimes longitudinally elliptical in surface view, 45–50 μ

in diam., oblong in transverse section, filled with a bright orange-yellow content; when those cells occur intermixedly with tetrasporangia on the same frond, they are larger than the latter and are in a marked contrast to those purplish structures. At first sight those gland-like cells bear some likeness in their appearance to hair "base-cells" which are frequently observed in various species of *Gracilaria* and *Gracilariopisis.* However, they differ from the hair "base-cells" in being markedly larger in size and bright orange yellow in color, and furthermore in lacking even a scar of hair. Judging from these characters, the writer is inclined to consider them to be "gland-cells". However, the true nature of these cells is not clear at present.

As regards the "gland-cells" in *Gracilaria* and allied genera, so far as the writer is aware, no one has ever reported their existence with the exception of Inagaki (1933), who described and illustrated "gland-cells" in his specimens of *Gracilaria confervoides* and *G. textorii* from Oshoro Bay, Hokkaido. He states that they are ovoid or elliptical in shape in transverse section, light yellow in color and refractive of light. He further states that similar "gland-cells" are present in *G. gigas*. As far as the present writer could determine from the specimens of these three species at hand, the "gland-like cells" were present only in *G. textorii* from Oshoro.

Tetrasporangia scattered amidst the superficial layer of frond, ovate to oblong as seen in transverse section, roundish in surface view, 30–50 μ in diam., cruciate, dark red or purplish in color but not in the sori, surrounded by somewhat modified cortical cells. Cystocarps and antheridia unknown.

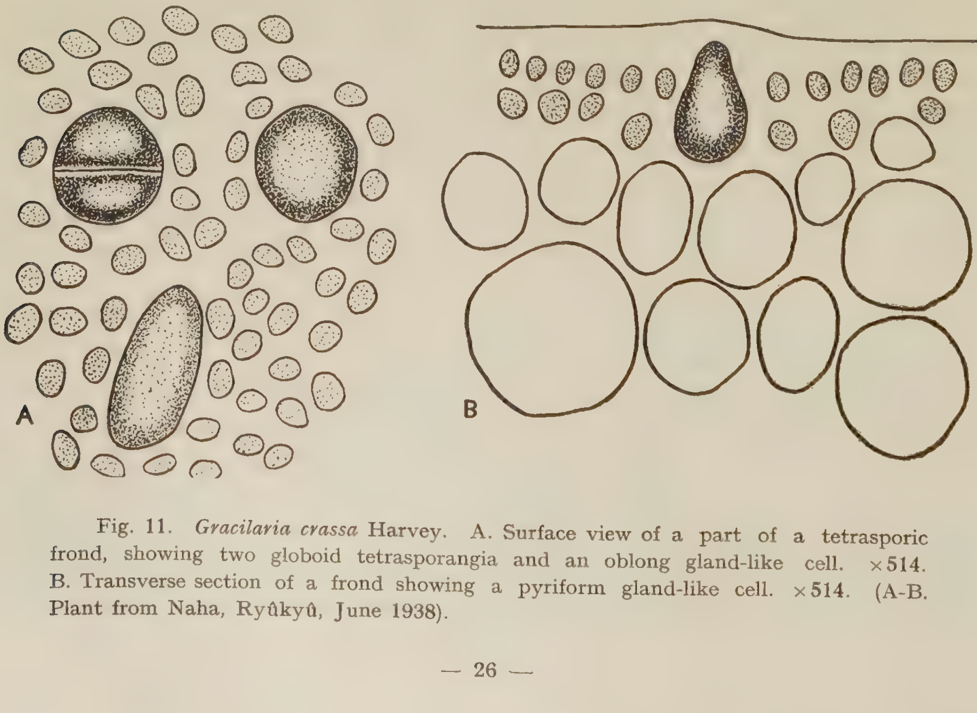


Fig. 11. *Gracilaria crassa* Harvey. A. Surface view of a part of a tetrasporic frond, showing two globoid tetrasporangia and an oblong gland-like cell. ×514. B. Transverse section of a frond showing a pyriform gland-like cell. ×514. (A-B. Plant from Naha, Ryûkyû, June 1938).

Börgesen (1952) and Dawson (1954, 1954a) made it clear that *Corallopsis opuntia* and *Gracilaria crassa* are one and the same species. Dawson (1954) states, "Although the constrictions of the pendant branches are extreme for the genus *Gracilaria*, they seem to constitute insufficient reason for generic segregation, particularly in view of the progressive approach to this condition exhibited by the development of *Gracilaria crassa* Harvey, ex. J. Agardh (=*Corallopsis opuntia* J. Ag.). Accordingly, the name *Corallopsis* Greville (1830, p. 53) is reduced under *Gracilaria* Greville (1830, p. 54)." After studying the specimens at hand, the present writer has come to agree with their views.

9. ***Gracilaria salicornia*** (C. Ag.) Dawson

Pl. V, F–VI, A, and Text-fig. 12.

Dawson, Notes on Tropical Pacific Marine Algae. Bull. South. Calif. Acad. Sci. 53 (1), 1954, p. 4, fig. 3. *Corallopsis salicornia* (C. Ag.) Grev. Alg. Brit. S. LIII; Kylin, Florideenord. Gigartinales, 1932, p. 58. *Sphaerococcus salicornia* C. Ag. Icon. Alg. ined., 1820, Taf. 8, Sp. Alg. p. 302.

Japanese name: *Tokida-fushikurenori* (n. n.).

Material examined: *Tokida* 24, ⊕, ♀, Itoman, Ryûkyû, June 1938.

Frond caespitose, cylindrical, 6–10 cm high, 2–2.5mm in diam., irregularly and repeatedly dichotomo-divaricately branched, greenish or yellowish red in color, soft cartilaginous in substance, adhering rather well to paper on drying; branches and branchlets conspicously articulato-constricted to a sharp spine, and because of this they are apt to be separated from the main axis at the sharpened base while treating; articulations obcuneate, oblong or elongated inverted pyriform, 2–15 times as long as broad. Frond in transverse section consisting of a medulla of large isodiametric parenchymatous cells, 260–350 μ in diam., with walls ca 8 μ thick, and two layers of small, anticlinally arranged pigmented cortical cells; transition from medulla to cortex is abrupt. Tetrasporangia scattered over almost entire surface of frond, round in shape in surface view, ovoid or oblong in transverse section, 15–20$\mu \times$45μ in dimensions, cruciate, bounded by somewhat anticlinally elongated cortical cells; gland-like cells abundantly scattered over the surface of frond, roundish or elliptical in surface view, 20–30 $\mu \times$ 30–45 μ in dimensions, oblong or pyriform in transverse section, 30 $\mu \times$ 45–60μ in dimensions, filled with a bright orange yellow content. When the gland-like cells occur intermixedly with tetrasporangia on the same frond, the latter are clearly distinguished from them by their smaller size and purplish color. As stated above, the gland-like cells are closely similar in their features to those of *Gracilaria crassa*. Cystocarps globoid, prominently protruding, non-rostrate, up to 1.8 mm in diam., constricted at the base; gonimoblast more or less lobulated, small-based, composed of conspicuously vacuolate cells; pericarp ca 240 μ in thickness, connected

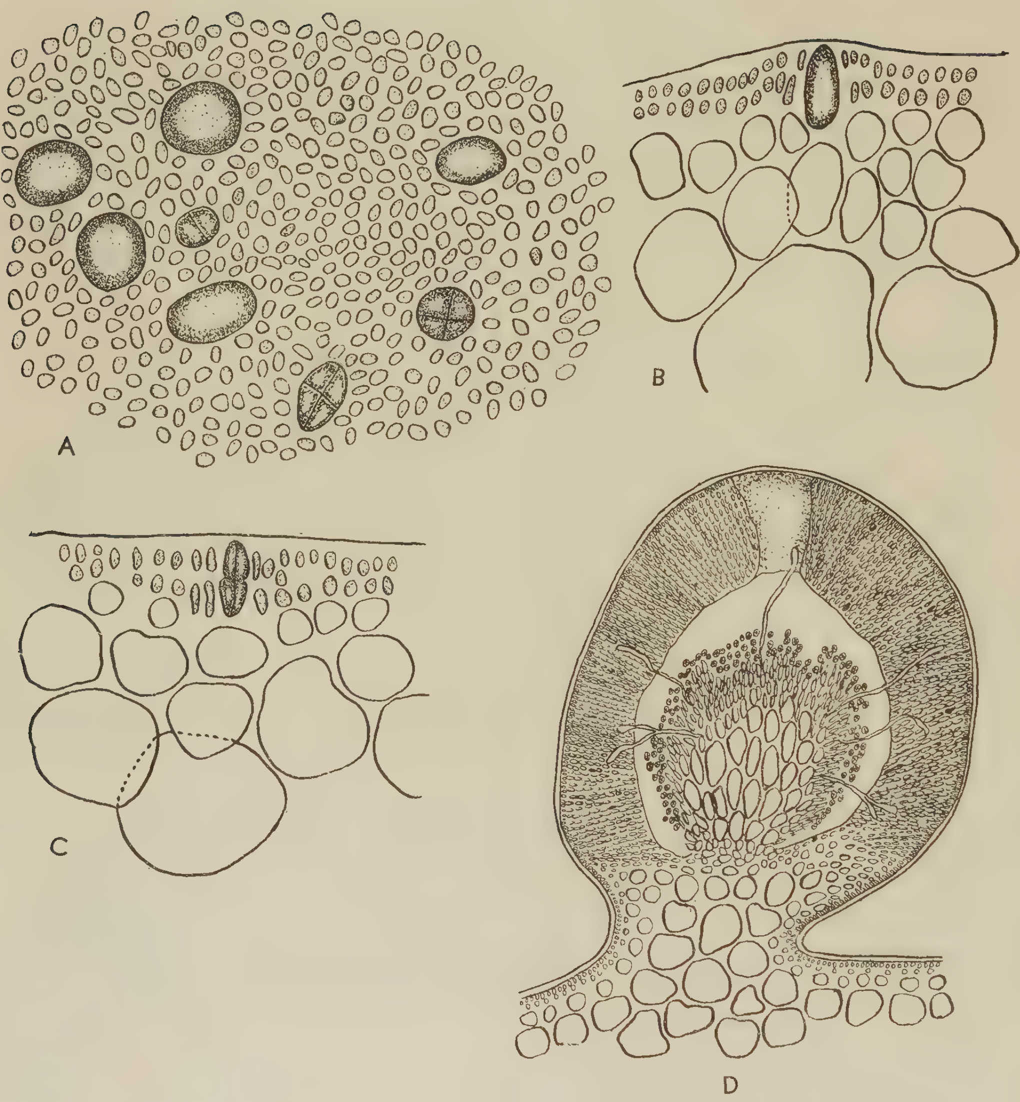


Fig. 12. *Gracilaria salicornia* (C. Ag.) Dawson. A. Surface view of a part of a tetrasporic frond to show three tetrasporangia and four gland-like cells scattered among cortical cells. ×284. B. Transverse section of a frond showing an oblong gland-like cell. ×284. C. Transverse section of a part of a tetrasporic frond. ×284. D. Section through a mature cystocarp. ×50. (A-D. Plant from Itoman, Ryûkyû, June 1938).

to gonimoblast by numerous nutritive filaments; carpospores round or ovoid, 15–20 μ in diam. at maturity. Antheridia unknown.

The present species closely resembles *Gracilaria crassa* in the internal structure as well as in the external character. However it is easily distinguished from the latter

in its extremely narrowed or sharply defined base of branches and branchlets. On the basis of comparison with the description and the illustration of the present species given by Dawson (1954), the specimens at hand can be referred to it without hesitation.

10. ***Gracilaria denticulata*** (Kütz.) Weber van Bosse

Pl. VI, B, and Text-fig. 13.

In De-Toni, Syll. Alg. VI, 1924, p. 265; Weber v. Bosse, Liste alg. Siboga. IV, 1928, p. 432; Yamada, Notes on Some Jap. Alg. VIII, 1938, p. 125, pl. 25, 2; Börg.,

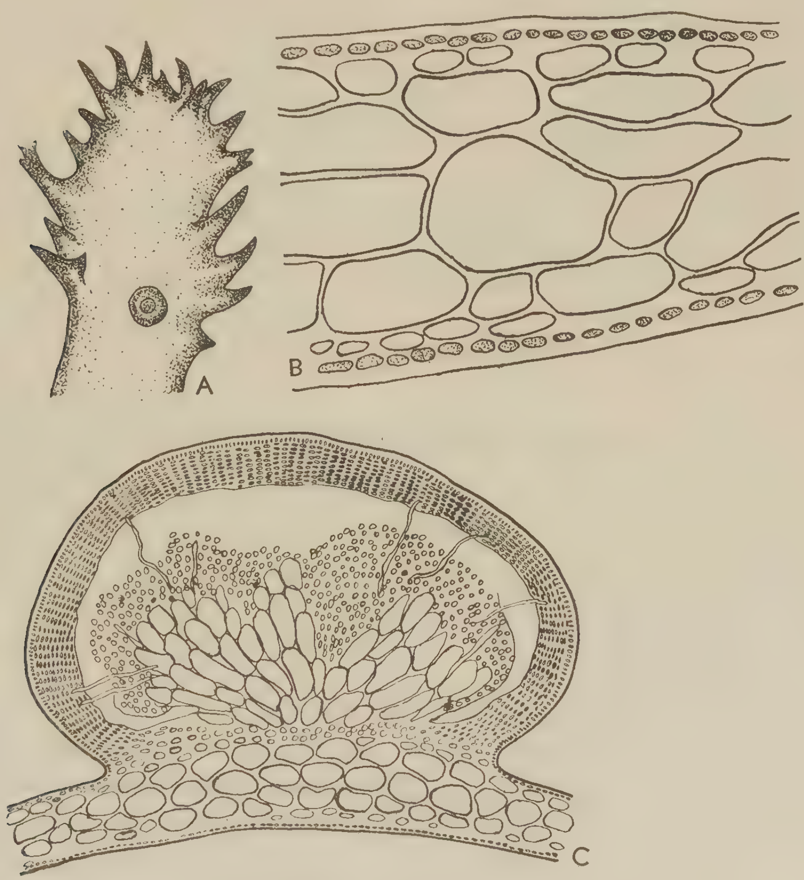


Fig. 13. *Gracilaria denticulata* (Kütz.) Weber van Bosse. A. Apical portion of a frond showing numerous denticulate processes on the margin. ×ca 5. B. Transverse section of a sterile frond. ×284. C. Section of a mature cystocarp. ×50. (A-C. Plant from Okinawa-jima, Ryûkyû, 1923).

Some Mar. Alg. fr. Mauritius. III, 1943, p. 76; Papenfuss, Notes on South Afr. Mar. Alg. III. 1951, p. 177. *Sphaerococcus denticulatus* Kütz., Tab. Phyc. XIX, 1869, p. 19, pl. 51, figs. e-g.

Japanese name: *Toge-kabanori.*

Material examined: *Sakaguchi*, Ryûkyû, 1923 (*Herb. B. H.* 21126 a-b, ♀; 21127, ♀; 21128 a-b, ♀).

Frond foliose, flabelliform, 8–10 cm high, 0.5–1.5 cm broad, provided with abundant denticulate processes on the margins, rosy to pinkish red, partially turning into yellowish color, coriaceous and slightly adherent to paper on drying, cylindrical and long stipe-like ca 4–5 cm in length below, arising from a small disc, repeatedly dichotomously lobed ending in blunt apices; frond in transverse section up to 180 μ thick when soaked in water, consisting of a medulla of 3–4 layers of large cells 160 μ in diam., and containing globular floridean starch grains, with a wall ca 3 μ thick, and a cortex of 1–2 layers of flattened cells 10–12 μ broad and 5 μ high with surface jelly ca 15 μ thick; infracortical cell is one-layered. Cystocarps on both surfaces of frond, prominent, globular, low dome-like in appearance, up to 1.75 mm in diam., ca 1 mm in height, non-rostrate, constricted at the base; gonimoblast lobulated, composed of large vacuolate cells, connected to the pericarp by several nutritive filaments; carpospores roundish or ovoid, 20–25 μ in diam. containing a rosy red chromatophore; pericarp up to 140 μ thick, constructed of a superficial layer of anticlinally erected small pigmented cells and about 10 layers of anticlinally arranged flat colorless cells. Tetrasporic and antheridial individuals unknown.

11. ***Gracilaria purpurascens*** (Harv.) J. Agardh

Pl. VI, C–D and Text-fig. 14.

J. Agardh, Till Alg. Syst. IV, 1885, p. 63; De-Toni, Syll. Alg. IV, 1900. p. 454; Id., *ibid.* VI, 1924, p. 271; Weber v. Bosse, Liste alg. Siboga IV, 1928, p. 437. *Gracilaria denticulata* Okam. (non Schmitz), Mar. alg. Kôtô-sho, 1931, p. 113; Yamada, Notes on Some Jap. Alg. VIII, 1938, p. 125, pl. 25, fig. 1. *Rhodymenia purpurascens* Harvey, Ceylon Alg., no 96 (nomen nudum).

Japanese name: *Murasaki-kabanori.*

Material examined: *Yamada*, Naha, Ryûkyû, May 1932 (*Herb. B. H.* 21121 a, ⊕, b, ♀, c, ⊕; 21122, a, b, ⊕, c, ♀; 21123, ♀; *Yamada*, Daibanratu, Formosa, 1923 (*Herb. B. H.* 21124, ⊕; 21125, ♀); *Fan* 1107-4, ⊕, Daibanratu, Formosa, Apr. 1951.

Frond foliose, flabellate, heavily crisped and furnished with numerous short spinulate processes on the margins, 6–8.5 cm high, 0.2–1.5 cm broad, less than 330 μ in thickness, dark red to purplish red or sometimes yellowish in color, coriaceous and adhering imperfectly to paper on drying, repeatedly dichotomously divided, ending in

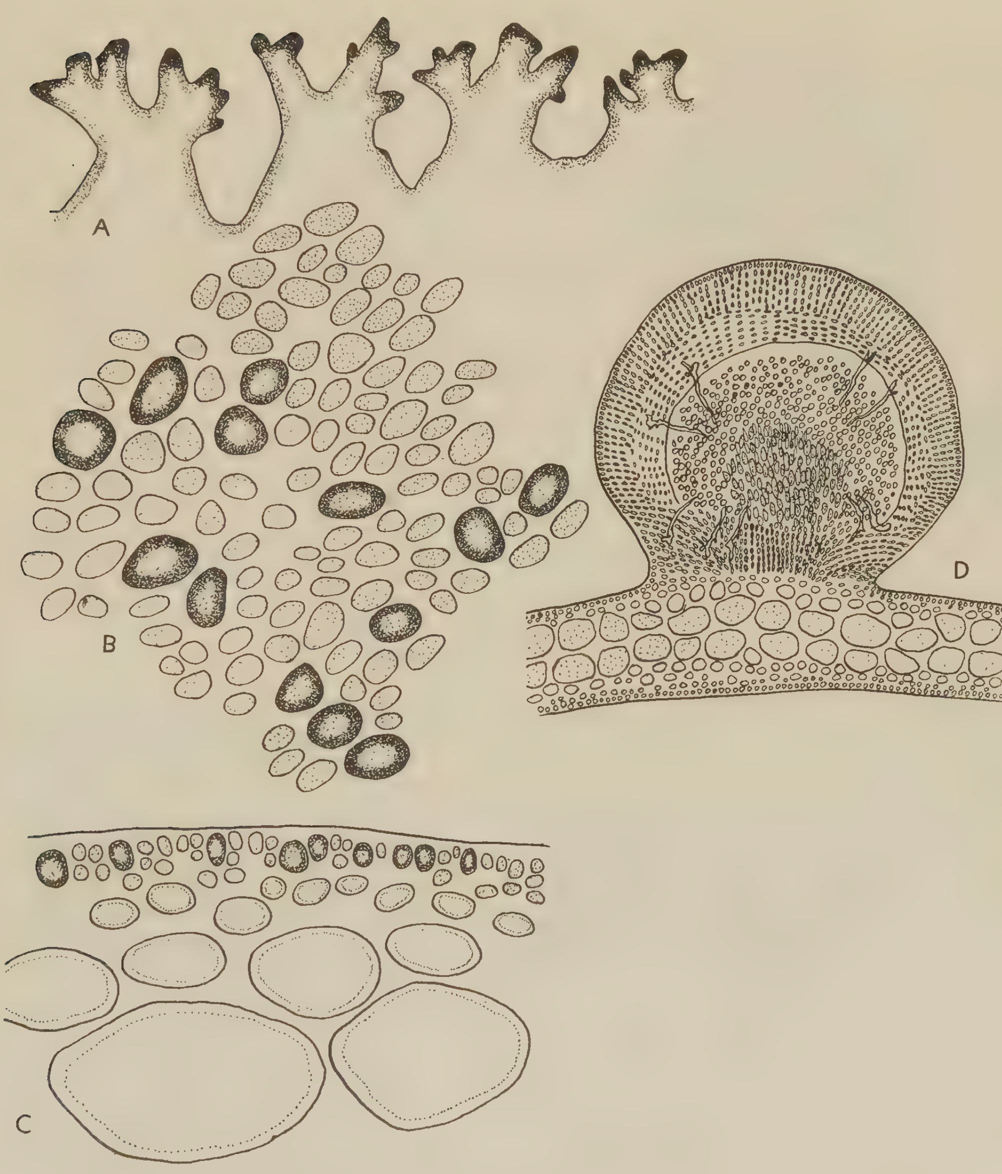


Fig. 14. *Gracilaria purpurascens* (Harv.) J. Ag. A. Detail of the crenulate margin of a frond. ×85. B. Surface view of a part of a tetrasporic frond. ×514. C. The same frond as seen in transverse section. ×284. D. Section of a mature cystocarp. ×50. (A-D. Plant from Naha, Ryûkyû, May 1932).

blunt or somewhat ligulate apices, arising from a small disc by a short cylindrical stipe, which expands into a cuneate base of the foliose frond; frond in transverse section consisting of a medulla of 2–3, rarely of 4 layers, of large roundish cells up to 160 μ in

diam., containing masses of globular floridean starch grains, with a wall 3–6 μ thick and an infracortex of one-layered somewhat flattened cells, 20 μ×30–45 μ in dimensions, bounded by two-layered small pigmented cortical cells, cuboid or sometimes more or less anticlinally elongated, 6 μ×10 μ in dimensions, with surface jelly up to ca 15–18 μ thick. Tetrasporangia densely scattered on both surfaces of entire frond, roundish and ca 15 μ in diam. in surface view, ovoid and 12 μ×18 μ in dimensions in sectional view, surrounded by unmodified cortical cells. Cystocarps prominent on both surfaces of frond, globular, low dome-like in appearance, non-rostrate, constricted at the base, 0.5–1.0 mm in diam., 0.4–0.9 mm in height; gonimoblast consisting of vacuolate cells, connected to the pericarp by abundant nutritive filaments 6 μ×180 μ in dimensions; carpospores small, roundish or oblong, 15–20 μ in diam.; pericarp 120–210 μ thick, composed of 10–15 layers of radially elongated outer cells and compressed inner cells.

11 a. ***Gracilaria purpurascens*** (Harv.) J. Agardh
f. ***spinulosa*** (Okam.) Yamada

Pl. VI, E–VII, B, and Text-figs. 15–16.

Yamada, Notes on Some Jap. Alg. IX, 1941, p. 204. *Rhodymenia spinulosa* Okam., Icon. Jap. Alg. VII, 1934, p. 33, pl. 318, figs. 1–6; Id., Nippon Kaisô-shi, 1936, p. 676.

Japanese name: *Toge-itsutsuginu.*

Material examined: *Tanaka*, Tairi, Formosa, Apr. 1934 (*Herb. B. H.* 21746 a, b, ♂; 21747 a, ⊕, b, ♀; 21748 a, ⊕, b, ♂); *Tokida* 17, sterile, Fukikaku, Formosa, May–June 1938; *Tokida* 21, ♀, Fukikaku, Formosa, May–June 1938; *Fan* 1003–1, ⊕, Garanbi, Formosa, Apr. 1951; *Fan* 1102–1, 2, ⊕, Garanbi, Apr. 1951; *Fan* 1103–1, ♀, Garanbi, Apr. 1951.

Frond foliose, flabellate, complanate, ca 6–9 cm high, 0.7–1.5 cm broad, seldom exceeding 350 μ, rarely up to 520 μ in thickness, often lacerated and furnished with abundant spinous processes on the margins, arising from a small disc by a short subterete stipe, expanding above into the cuneate base of the foliose frond, dull red to purplish russet or yellowish green in color, carnose in substance while fresh, but becoming subcartilaginous and adhering not well to paper on drying; branching dichotomous; branches ending in obtuse or occasionally somewhat truncate tips; frond in transverse section consisting of a medulla of 3–4 layers of cells containing numerous globular floridean starch grains 5–6 μ in diam., with cell walls ca 6 μ thick, diminishing in diameter towards the exterior, grading into an infracortex of 2–3 layers of cells, bounded by a cortex of two layers of minute pigmented cells mostly cuboid, ca 6 μ×9 μ in dimensions, which are roundish and ca 10 μ in diam. in surface view,

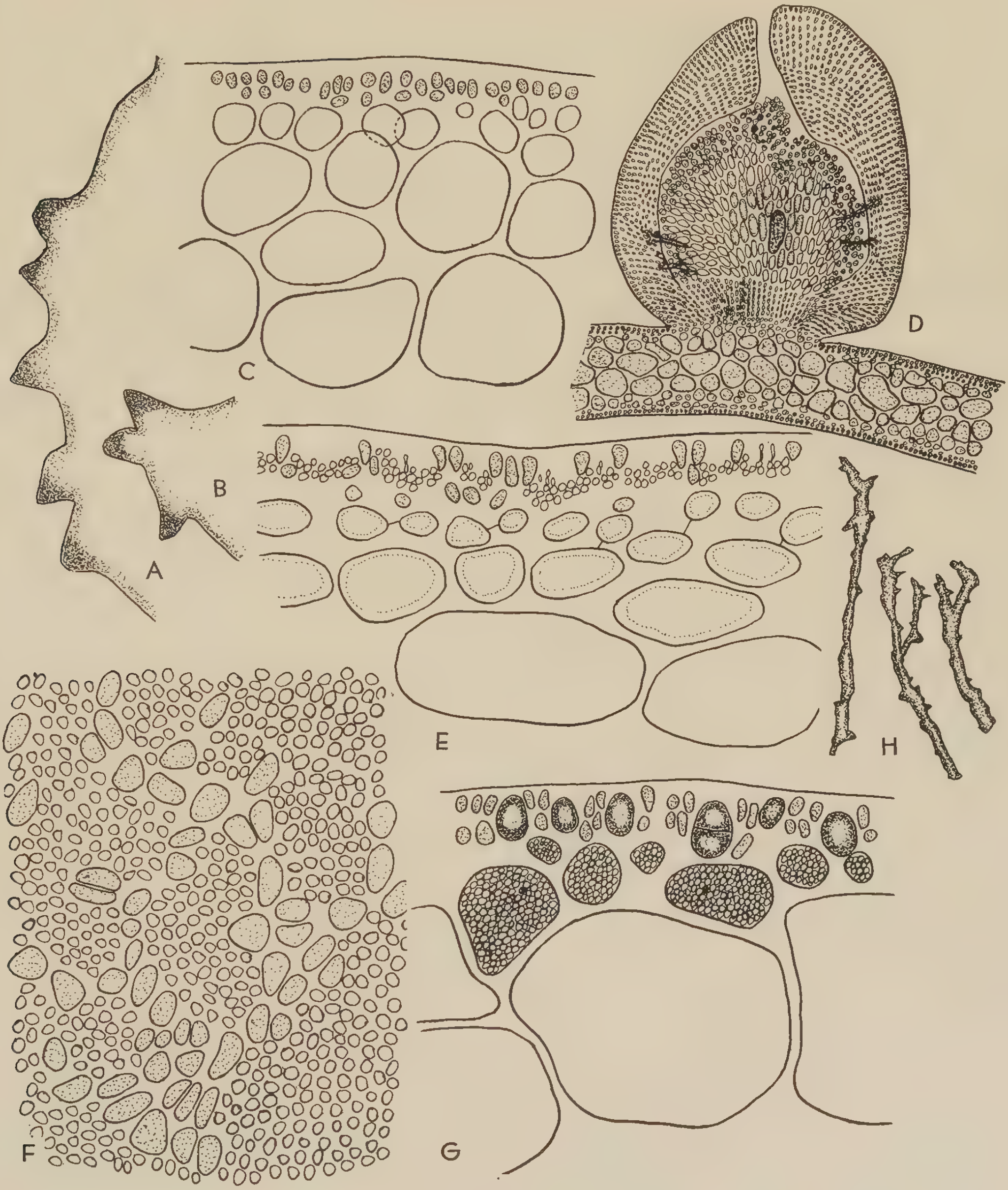


Fig. 15. *Gracilaria purpurascens* f. *spinulosa* (Okam.) Yamada. A. Detail of the margin of a frond bearing spinous processes. ×50. B. A compound marginal process of the same frond as in fig. A, highly magnified. ×284. C. Transverse section of a sterile frond. ×284. D. Longitudinal section through the center of a cystocarp, showing the ostiole and the fusion cell measuring 45μ broad and 120μ long. ×50. E. Transverse section of an antheridial frond showing antheridial pits and modified cortical cells. ×284. F. The same antheridial frond in surface view. ×514. G. Transverse section of a tetrasporic frond. ×284. H. Detail of three nutritive filaments. ×284. (A-F. Plant from Tairi, Formosa, Apr. 1934. G-H. Plant from Garanbi, Formosa, Apr. 1951).

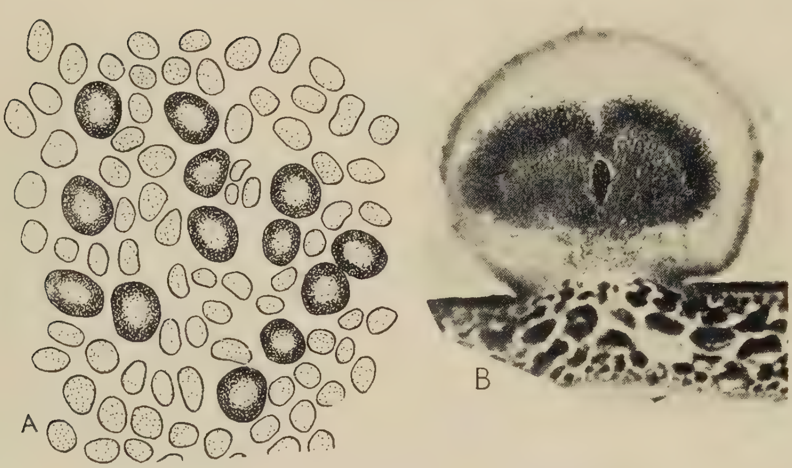


Fig. 16. *Gracilaria purpurascens* f. *spinulosa* (Okam.) Yamada. A. Surface view of a part of a tetrasporic frond. ×514. B. Microphotograph of a mature cystocarp showing the gonimoblast with a conspicous fusion cell in the center and the nutritive filaments. ×54. (A. Plant from Tairi, Formosa, Apr. 1934. B. Plant from Garanbi, Formosa, Apr. 1951).

with surface jelly 6–10 μ thick. Tetrasporangia roundish or ovoid and densely scattered over both surfaces of entire frond, borne in a slightly modified cortex, 10–22 μ ×18–27 μ in dimensions in transverse section, roundish and up to 18 μ in diam. in surface view, cruciate. Cystocarps scattered on both surfaces of frond, exceedingly prominent, low dome-like or almost globular in appearance, reaching 0.8–1.3 mm in diam., ca 0.7–1.0 mm in height at maturity, non-rostrate, strongly constricted at the base; gonimoblast sometimes lobed, formed of vacuolate cells, seated on the floor which is ca 120 μ thick and composed of 5–6 layers of radially arranged cells; nutritive filaments connecting the gonimoblast to the pericarp solid and thick, ca 6 μ thick and ca 105 μ long; carpospores rather small, ovoid or roundish, 15–22 μ in diam., compactly filling the cystocarpic cavity; pericarp 120–350 μ in thickness, consisting of many layers of small cells, of which the outermost pigmented cells are anticlinally erect, 5–6 μ×9–12 μ in dimensions, while inner colorless ones more or less flattened, anticlinally arranged in 20–26 layers. Antheridia borne in solitary or confluent shallow, broad pits, 15–20 μ in depth, 15–30 μ or more in breadth, surrounded by modified cortical cells.

The present species seems to come very near *Gracilaria millardetii* (Mont.) J. Ag. However it can easily be distinguished from the latter in having shallow pit-like antheridial cavities.

12. ***Gracilaria punctata*** (Okam.) Yamada

Pl. VII, C–VIII, B, and Text-figs. 17–18.

Yamada, Notes on Some Jap. Alg. IX, 1941, p. 203. *Rhodymenia punctata* Okam., Icon. Jap. Alg. VI, 1929, p. 13, pl. 258; Id., Nippon Kaisô-shi, 1936, p. 676.

Japanese name: *Itsutsu-ginu.*

Material examined: *Tanaka*, Tairi, Formosa, Apr. 1934 (*Herb. B. H.* 21753 a-b, ⊕, c, ♀; 21754 a, ⊕, b, ♀; 21755 a, ♀, b, ⊕); *Yamada*, Garanbi, Formosa, Apr. 1934 (*Herb. B. H.* 21756 a-d, ⊕; 21757 a, ♂, b, ⊕; 21759 a, ♂, b, ⊕, c, ♂); *Tanaka*, Tairi, Formosa, Apr. 1934 (*Herb. B. H.* 21760 a-b, ♂, c, sterile, d, ♂); *Nakamura*, Uchino-ura, Kagoshima Pref., Aug. 1940 (*Herb. B. H.* 24123, ⊕); *Tokida* 10, ⊕, ♀, sterile, Garanbi, Formosa, May 1938; *Umezaki*, Shirahama, Wakayama Pref., March 1952 (*Herb. Ohmi* 55, sterile; 56, ⊕).

Frond complanate, foliose, 5–10 cm long, 1–2.5 cm broad, dichotomously divided, often markedly contracted in the middle portion of the lobes, obtuse or irregularly cleft in apices, sometimes arcuated at the upper portion of frond, possessing a general outline oblong or ovate or sometimes like an inverted triangle, arising from a small discoid holdfast attached to coralline crust by a short terete stipe expanding into the cuneate base of the foliose frond, which is undulate or crisped and entire or infrequently provided with small protuberances on the margin, variegated here and there on the surface with elliptical spots measuring ca 0.5 mm×0.7 mm in dimensions; dark red or purplish russet, often becoming slightly greenish in color, thickly membranaceous or cartilaginous in substance while fresh, becoming coriaceous and poorly adhering to paper on drying; frond in transverse section up to 450 μ in thickness, consisting of a medulla of 2–3, rarely up to 4, layers of large cells 105 μ in diam., and an infracortex of two-layered smaller cells, bounded by a cortex of 2–3 layers of cells, cuboid or somewhat anticlinally elongated, mostly 6–10 μ×10–12 μ in dimensions; cells of medulla and infracortex are both filled in the content with innumerable floridean starch grains, which are globular in shape, reaching 6 μ in diam., and with walls less than 8 μ in thickness. Tetrasporangia densely scattered on both surfaces of frond, ovoid, 20–30 μ high and 10–24 μ broad in transverse section, roundish in surface view, dark red in color, in unmodified cortical cells; in an old tetrasporic frond can be frequently seen small whitish specks on the surface. Cystocarps scattered on both surfaces of frond, prominently protruding, up to 3 mm in diam., 1.2 mm in height at maturity, dome-like in appearance, non-rostrate, strongly constricted at the base; gonimoblast consisting of large vacuolate cells, connected to the pericarp by nutritive filaments; carpospores roundish or oblong, 20 μ in diam. to 15 μ×30 μ in dimensions, almost filling the cystocarpic cavity; pericarp ca 200 μ thick, consisting of 1–2 superficial layers of

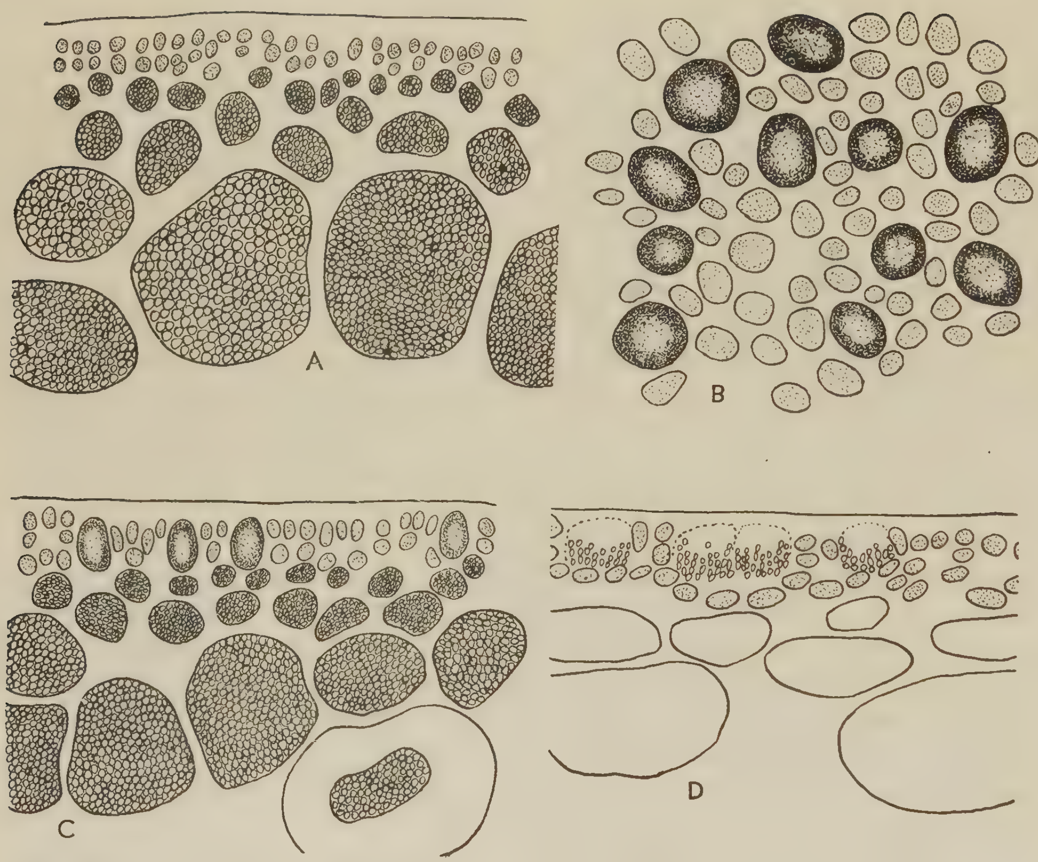


Fig. 17. *Gracilaria punctata* (Okam.) Yamada. A. Transverse section of a sterile frond. ×284. B. Surface view of a tetrasporic frond. ×514. C. Transverse section of the same tetrasporic frond. ×284. D. Transverse section of an antheridial frond showing antheridial pits. ×284. (A-D. Plant from Garanbi, Formosa, Apr. 1934).

anticlinally erect pigmented cells, $6\mu \times 15\mu$ in dimensions, and 8–12 inner layers of colorless, irregularly shaped, more or less anticlinally arranged cells; surface jelly 13μ thick.

The above description is a modification of that given by Yamada (1941).

Antheridia borne in solitary or confluent, small, shallow, saucer-like antheridial pits $10–20\mu$ deep and $20–45\mu$ diam., surrounded by more or less modified cortical cells; in surface view antheridial sori densely scattered over the greater part of the frond surface as small white flecks separated by islands of linear or lenticular groups of vegetative cells.

The present species seems to bear some resemblance in its texture to *Gracilaria crispata* Setchell et Gardner as was already pointed by Yamada. However, after

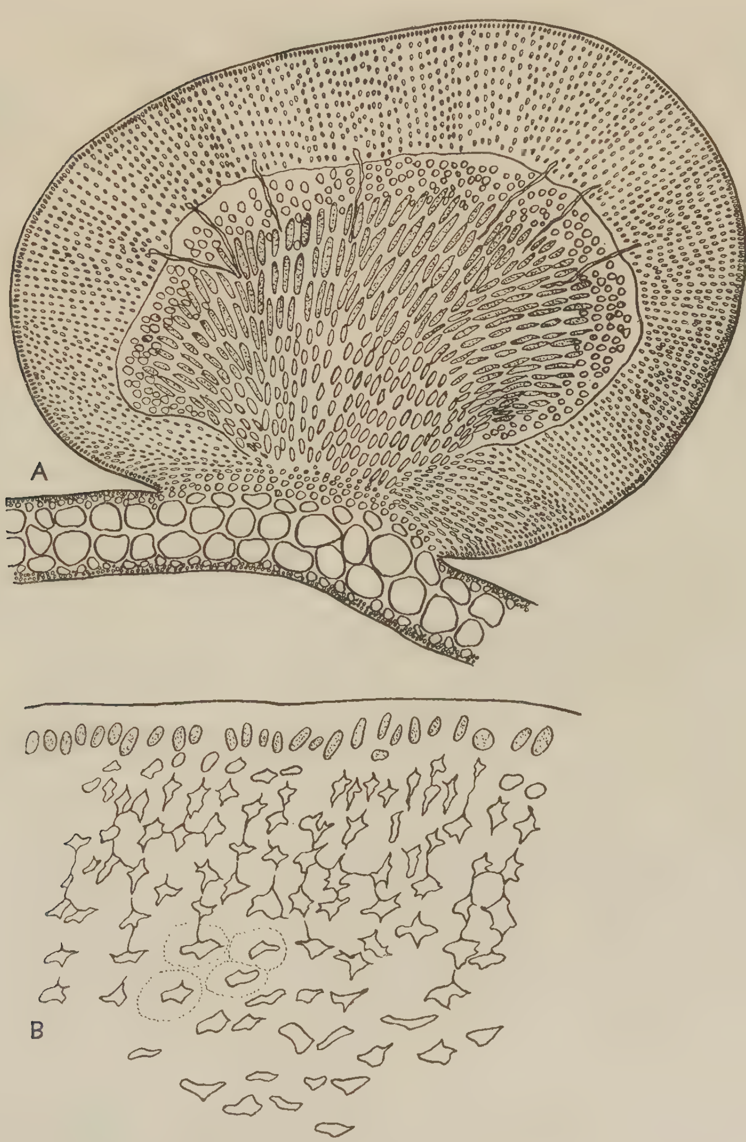


Fig. 18. *Gracilaria punctata* (Okam.) Yamada. A. Section of mature cystocarp. ×50. B. Detail of the pericarp of the cystocarp shown in fig. A. ×284. (A-B. Plant from Garanbi, Formosa, May 1938).

compa riting with the specimens of the latter now at hand (*Dawson* 1713, ⊕, Bahia Bocochibampo, near Guaymas, Sonora, May 1946; *Dawson* 3470, ♀, Bahia de La Paz, Baja Calif., overcast, Nov. 1946; *Dawson* 3552, ♀, Ensenada de San Francisco, near Guaymas, Sonora, Nov. 1946), the present writer can distinguish it from the latter by its

broader frond and thinner cortical layer. Among the Formosan specimens the writer was able to find five antheridial individuals so he could confirm Okamura's observation on the structure of the antheridial cavity.

13. ***Gracilaria incurvata*** Okam.

Pl. VIII, C–IX, B, and Text-fig. 19.

Okam., Icon. Jap. Alg. VI, 1931, p. 41. 273, figs. 1–6; Id., Nippon Kaisô-shi, 1936, p. 633.

Japanese name: *Mizo-ogonori.*

Material examined: *Tokida* 2, sterile, Jyôga-shima, Kanagawa Pref., Apr. 1938; *Umezaki*, Shirahama, Wakayama Pref., May 1951 (*Herb. Ohmi* 3–4, ⊕); *Yagi*, Mitsuhama, Ehime Pref., July 1953 (*Herb. Ohmi* 30, ⊕); *Yagi*, Mistsuhama, Ehime Pref., Aug. 1953 (*Herb. Ohmi* 31–32, ⊕); *Yagi*, Takahama, Ehime Pref., Aug. 1953 (*Herb. Ohmi* 33–34, ⊕); *Yagi*, Kuroiwa, Ehime Pref., Aug. 1953 (*Herb. Ohmi* 35, 74, ⊕); *Yagi*, Mimatoyama, Ehime Pref., Aug. 1953 (*Herb. Ohmi* 36, ⊕); *Yagi*, Minatoyama, Ehime Pref., Aug. 1955 (*Herb. Ohmi* 37–38, ⊕); *Yagi*, Takahama, Ehime Pref., Aug. 1953 (*Herb. Ohmi* 39, ♀); *Yagi*, Umezudera, Ehime Pref., Aug. 1953 (*Herb. Ohmi* 41, ♀); *Yagi*, Mistuhama, Ehime Pref., Aug. 1953 (*Herb. Ohmi* 42, ♀); *Yagi*, Yanagihara, Ehime Pref., Aug. 1953 (*Herb. Ohmi* 43, ♀); Yagi, Mistsuhama, Ehime Pref., Aug. 1953 (*Herb. Ohmi* 44, ♀); *Yagi*, Takahama, Ehime Pref., Aug. 1953 (*Herb. Ohmi* 45–46, ♀); *Yagi*, Mitsuhama, Ehime Pref., Nov. 1953 (*Herb. Ohmi* 47, ♀); *Yagi*, Gogo-shima, Ehime Pref., Aug. 1955 (*Herb. Ohmi* 48, ♀); *Yagi*, Minatoyama, Ehime Pref., Aug. 1955 (*Herb. Ohmi* 49, ♀); *Yagi*, Mitsuhama, Ehime Pref., Aug. 1953 (*Herb. Ohmi* 50, sterile); *Yagi*, Minatoyama, Ehime Pref., Aug. 1955 (*Herb. Ohmi* 51, sterile).

Plant foliose, caespitose and massive, erect, 6–14 cm high, more or less flabelliform, arising from a callous disc; frond flat or compressed except the very base, reaching a thickness of 0.6–0.8 mm, rarely up to 1.2 mm, provided with numerous dichotomous lobes above the first fork at fairly short intervals, with patent round axils, channeled or more or less incurved and often twisted at some part; branches tapering upwards in some cases, but almost equal in breadth in others, ending in blunt or long attenuated bifurcate apices, and occasionally arcuated at upper lobes, sometimes furnished with short adventitious proliferations on both surfaces and margins, broadly linear or band-shaped, 5–10 mm up to 15 mm in breadth, abruptly narrowed at the base to a very short, subcylindrical stipe; segments slightly tapered in some specimens, 0.3–2 mm in breadth below the apex; margins smooth and entire. Coriaceous and brittle in substance when fresh, imperfectly adhering to paper on drying; frond in transverse section consisting of a medulla of large, normally 5–6 layered, thin-walled cells with walls less than 6 μ in thickness, up to $350\mu \times 610\mu$ in dimensions, and an infracortex of 2–3 layered cells, mostly somewhat compressed interconnected by distinct filaments between each

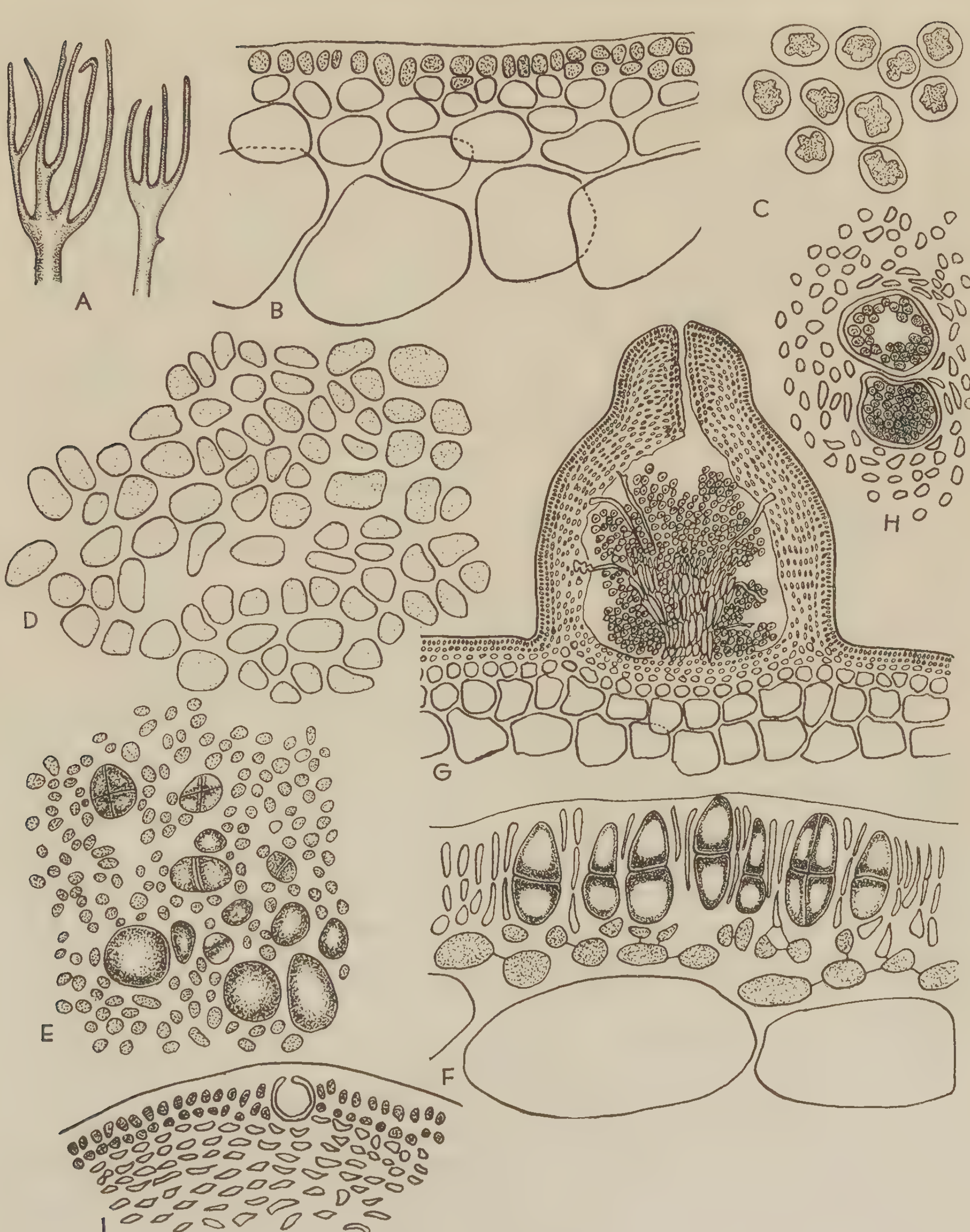


Fig. 19. *Gracilaria incurvata* Okam. A. Habit of the terminal portion of branches showing long attenuated bifurcate apices. ×4/3. B. Transverse section of a sterile frond. ×284. C. Detail of carpospores. ×284. D. Surface view of a sterile frond. ×514. E. Surface view of a tetrasporic frond. ×284. F. The same tetrasporic frond in transverse section. ×284. G. Section of a mature cystocarp. ×50. H. *Chlorochytrium*-like endophytes embedded in the pericarp as seen from surface. ×284. I. Part of the same pericarp with an emptied endophyte in transverse section. ×284. (A-I. Plant from Takahama, Ehime Pref., Aug. 1953).

other, containing numerous floridean starch grains, bounded by a cortex of a single or sometimes two-layered pigmented cells 3–5 μ thick, 6–9 μ high anticlinally erect, which in surface view are from 4 μ in diam. to $10\mu \times 14\mu$ in dimensions, with surface jelly ca 5 μ thick. Tetrasporangia densely scattered over both surfaces of frond, bright red in color, ovate to oblong, cruciate, $12–35\mu \times 40–65\mu$ in dimensions in transverse section, $12\mu \times 30\mu$ to $30\mu \times 45\mu$ in surface view, surrounded by modified cortical cells. Cystocarps globose, prominently rostrate, scattered over both surfaces of frond, 0.7–1.5 mm in diam.; gonimoblast built up of large parenchymatous cells, connected to the pericarp by nutritive filaments; pericarp 105–150 μ in thickness, constructed of many-layered cells, of which the outermost ones are strongly pigmented and somewhat anticlinally elongated, while the inner colorless cells are rather flat in shape; mature carpospores spherical 20–36 μ in diam. with a reddish chromatophore in the center. Antheridial plant unknown. The specimens from Takamatsu, Ehime Prefecture are found to bear a number of spherical bodies of an endophyte, scattered over the frond surface and embedded in the cortex of the greater parts of a frond as well as in the pericarp of a cystocarp. They are 18–25 μ in diam. and have a colorless wall 2.5 μ thick. They often contain many swarmer-like globules, which are 5–6 μ in diam. and grass-green in color, but most of them are empty being provided with an apical aperture. This endophyte may probably be a species of *Chlorochytrium*.

The present plant bears a close resemblance to *Gracilaria textorii*, with which it had been confused till Okamura (1931) made their differences clear and erected a new species for the plant. He says that the frond of the present species is smaller, less broad, incurved or somewhat distorted, and closely dichotomous in branching as compared with that of *G. textorii*. However, he further continues, "All those differences are not always strongly manifest, but there are often intermediate forms between it and *G. textorii*." In present writer's opinion, this species is decidedly distinguishable from. *G. textorii* in having not only the above mentioned characteristics but also long attenuated terminal branches and strongly rostrate cystocarps.

14. ***Gracilaria textorii*** (Suringar) J. Agardh

Text-figs. 20–21.

J. Agardh, Sp. Alg. III, 1. Epicr., 1876, p. 426; De-Toni, Phyc. Jap. Nov., 1895, p. 27, n. 52; Okam., Alg. Jap. Exsic. no. 133, 1899; De-Toni, Syll. Alg. IV, 1900, p. 449; Okam., Illust. Mar. Alg. Jap., I (5), 1901, p. 65, pl. 23; Inagaki, Mar. Red Alg. Oshoro Bay, Hokkaido and its Adj. Waters, 1933, p. 37, fig. 12; Okam., Nippon Kaisô-shi, 1936, p. 632; Ohmi, Contr. Knowledge of Gracilariaceae fr. Jap. I, 1955, p. 320, pls. 1–6. *Sphaerococcus* (*Rhodymenia*) *textorii* Suring., Index praecursorius., 1867, p. 259; Id., Alg. Jap., 1870, p. 36. *Gracilaria vivesii* Howe, Phyc. Stud. V, 1911, p. 503, pl. 30, 33; Dawson, Stud. Northeast Pacif. Gracilariaceae, 1949, p. 34, pl. 2, figs. 4–6, pl.

14, figs. 1–6, pl. 15, figs. 1–6. *Gracilaria johnstonii* Set. et Gard., Mar. Alg. in Exped. Calif. Acad. Sci. to the Gulf of Calif. in 1921, 1924, p. 752, pl. 22, figs. 11–14, pl. 60; Dawson, Mar. Alg. Gulf of Calif., 1944, p. 293. *Gracilaria sinicola* Set. et Gard., 1. c., 1924, p. 752, pl. 62. *Gracilaria vivipara* Set. et Gard., 1. c., 1924, p. 750, pl. 24, figs. 28, 29, pl. 63.

Japanese name : *Kaba-nori*.

Material examined : *Chihara*, Susaki near Shimoda, Shizuoka Pref., June 1955 (*Herb. Ohmi* 91–95, ⊕; 95–105, ♀); *Ohmi* 106, ♂, Oshoro, Hokkaido, Nov. 1954; *Segawa*, Ôyano-shima, Kumamoto Pref., Apr. 1955 (*Herb. Ohmi* 107, ♂); *Ohmi* 108, ♀, Oshoro, Hokkaido, Nov. 1954; *Ueda*, Kominato, Chiba Pref., May 1950 (*Herb. Ohmi* 109, ♀); *Ohmi* 110, ♂, Oshoro, Hokkaido, Nov. 1954; *Umezaki*, Shirahama, Wakayama Pref., June 1951 (*Herb. Ohmi* 111–112, ⊕); *Ohmi* 113, ⊕, Oshoro, Hokkaido, Nov. 1954; *Yendo* (without number), ⊕, Chiba Pref., July 1902.

Plants foliose, caespitose, arising from a common scutate disc, with a short subcylindrical stipe, soon expanding into the cuneate base of frond, irregularly dichotomously to flabellately lobed with broad linear patent segments whose axils are rounded; dull- or brownish-red to somewhat yellowish or greenish in color, membranous to thick coriaceous in substance, imperfectly adhering to paper on drying; frond variable in size and shape, usually 4.7–18.5 cm high and 7–45 mm broad under the dichotomies when mature, with rounded or somewhat attenuated apices, also variable in thickness, young plants being quite thin (240μ), while old ones may be as much as 750–875μ thick; margins smooth and entire, occasionally slightly undulate, normally non-proliferous but sometimes with more or less simple or branched proliferations; apical segments, 0.5–7 mm broad below the apex, sometimes end in blunt or ligulate, or sometimes in acute or bifid apices; in other cases, terminal segments are much slenderer and more pale in color than the remaining portion, being divided repeatedly in dichotomous manner; frond in transverse section consisting of a prominent cellular medulla of large (230–400μ in diam.) thin-walled (5–9μ thick) cells, which are colorless in content; cortex normally made of a pigmented single layer of more or less anticlinally elongated cells, which in older parts become two-layered, measuring 5–12μ long, 4–9μ broad; subcortical layers of somewhat larger cells, containing globular floridean starch grains which are 3–7μ in diam.; transition from the large medullary cells to the small cells of the cortex is abrupt; colorless hairs occasionally present on frond surface, measuring up to 320μ long and 6μ thick; surface jelly thin. Tetrasporangia are densely scattered over both surfaces of the frond except the apical and the lowermost portions, ovate to elongate in shape, attaining $22\mu\times13\mu$–$35\mu\times28\mu$ in transverse section and $8.5\mu\times8.5\mu$–$40\mu\times22\mu$ in surface view, cruciately divided. They are bright red in color.

Sexual plants are heterothallic.

Cystocarps hemispherical or almost globular, up to 1.7 mm in diam., ostiolate,

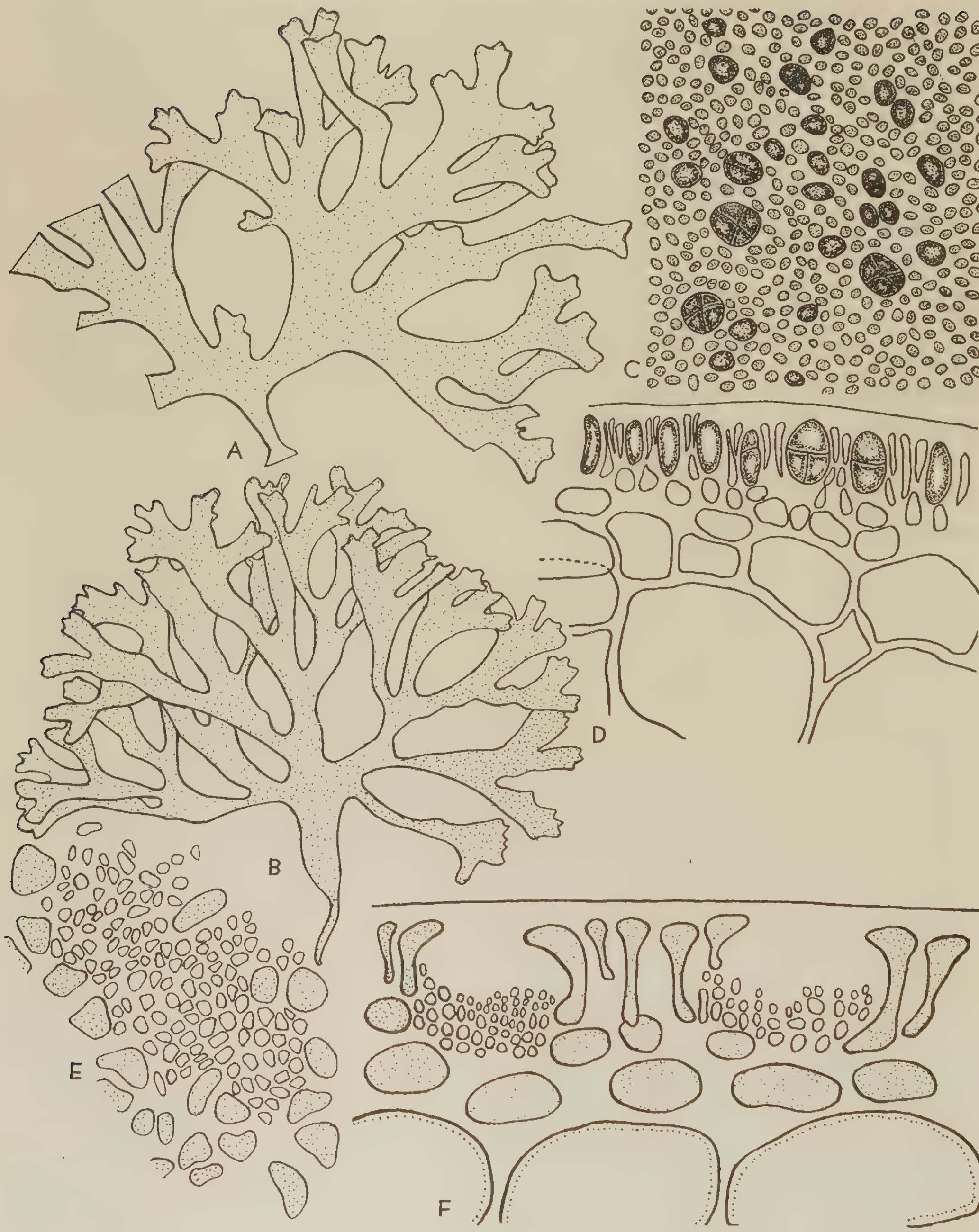


Fig. 20. *Gracilaria textorii* (Sur.) J. Ag. A-B. Habit of two antheridial plants. ×ca 2/3. C. Surface view of a tetrasporic frond. ×284. D. The same tetrasporic frond in transverse section. ×284. E. Surface view of an antheridial frond. ×514. F. The same antheridial frond in transverse section. ×514. (A, E-F. Plant from Ôyano-shima, Kumamoto Pref., Apr. 1955. B-D. Plant from Oshoro, Otaru, Hokkaido, Nov. 1954).

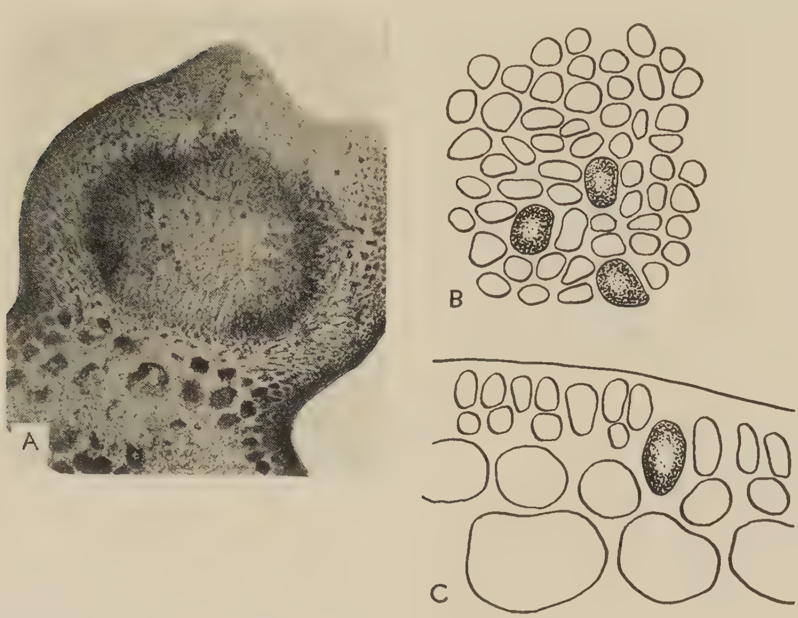


Fig. 21. *Gracilaria textorii* (Sur.) J. Ag. A. Microphotograph of a mature cystocarp in section. ×30. B. Surface view of a cystocarpic plant to show three gland-like cells among the cortical cells. ×514. C. The same cystocarpic plant in transverse section to show an ovoid gland-like cell. ×514. (Plant from Oshoro, Otaru, Hokkaido, Nov. 1954).

densely scattered over both surfaces of frond; pericarp thick, being constructed of many layers of cells, which are anticlinally elongated; gonimoblast nearly filling the cystocarpic cavity and keeping connection with the pericarp by means of numerous nutritive filaments; nutritive filaments irregularly shaped, 105–180 μ long, 10–20 μ broad; outermost cells of the pericarp red in color, 9–15 μ long, 6–9 μ broad, while inner ones are yellowish in color or almost colorless; carpospores spherical or slightly elongated in shape, measuring $13\mu \times 9\mu$–$28\mu \times 22\mu$, having a red chromatophore in the central portion.

Male frond is sometimes distinguishable by its pale red color from others. Antheridia are borne abundantly all over the surfaces of frond, in superficial shallow saucer- or cup-like cavities or pits, 20 μ wide, 17 μ deep, surrounded by modified, pigmented cortical cells. Antheridial pits are formed at first solitarily, but later become adjoining side by side or even confluent. Spermatia are colorless, globular, mostly 2–3 μ in diam. as seen from surface.

A thorough description and remarks on this species are given in the writer's previous paper cited above.

Among the specimens in the Herbarium of the Departemnt of Botany, Faculty

of Science, Hokkaido University, a large tetrasporic frond (*Herb. B. H.* 25481) collected by S. Sakaguchi in Wakayama Pref., in June 1943 was found to measure 30 cm in length, and 6 cm in breadth. It is the largest specimen of this species the writer has ever examined. A specimen from Ôyano-shima, Kumamoto Pref. was found to bear antheridia in broad, shallow cup-like cavities bounded by conspicuously modified cortical cells as shown in Fig. 20, F. In a tetrasporic specimen from Oshoro, Hokkaido, the tetrasporangia were observed to be bounded by slightly modified cortical cells as figured in Pl. I, Fig. 3 of the writer's previous paper (1955). However, in other specimens from the same locality which bear abundant tetrasporangia the cortical cells are considerably modified (Fig. 20, D).

On reexamining the specimens collected at Oshoro in November 1954, the present writer could observe gland-like cells scattered over the surface of frond, light yellow or pale red in color, roundish, more or less larger in dimensions than the adjoining cortical cells when observed in surface view, and ovoid in shape as viewed in transverse section, measuring $6\mu \times 10$–15μ. They correspond closely to the "gland-cells" which were described and illustrated by Inagaki (1933). However their true nature is not clear to the present writer at the moment.

15. ***Gracilaria sublittoralis*** Yamada et Segawa (*nom. nud.*)

Pl. IX, C–D, and Text-fig. 22.

In Takamine et Yamada, A List of Marine Algae of Sugashima, Ise Bay (in Japanese). Bot. Mag. Tokyo, 63(750), 1950, p. 268.

Japanese name: *Shinkai-kabanori.*

Material examined: *Segawa*, Kôzu-shima, Izu Isl., Aug. 1936 (*Herb. Ohmi* 53 a, ⊕); *Segawa*, Kôzu-shima, Izu Isl., July 1937 (*Herb. Ohmi* 53 b, ⊕); *Yagi*, Uwajima, Ehime Pref., May 1955 (*Herb. Ohmi* 54, ⊕).

This species was recently added to the list of the species of *Gracilaria* by the above mentioned authors without giving any diagnosis or illustrations. Through the kindness of Dr. Segawa and Mr. Yagi, present writer was fortunately able to examine some specimens including three tetrasporic and one cystocarpic plants.

Plant complanate, foliose, irregularly and sparingly lobed into broad linear patent segments with round axils, brownish red in color, membranous to thick coriaceous in substance, adhering imperfectly to paper on drying, rather variable in size and shape, when matured reaching 20 cm in length, 3–6 cm in breadth, blunt or ligulate at the apex, smooth and entire on the margins, provided with a few proliferations or sometimes non-proliferous; frond in transverse section seen to consist of a medulla of large cells 260–600μ in diam., roundish or polygonal and thin-walled (ca 6μ thick), bounded by a single layered infracortex or in older parts it may become distromatic to rarely three layered; cortex of pigmented cells, minute, irregularly shaped, mostly



Fig. 22. *Gracilaria sublittoralis* Yamada et Segawa. A. Transverse section of a sterile frond. ×284. B. Surface view of a tetrasporic frond. ×284. C. The same tetrasporic frond in transverse section. ×284. D. Detail of the pericarp of a cystocarp. ×284. E. Outlines in section of two cystocarps showing the low dome-like shape. ×13. F. Section of a mature cystocarp. ×50. G. Detail of carpospores. ×284. (A-G. Plant from Kôzushima, Izu Islands, Aug. 1936).

3–4 $\mu \times 6 \mu$, reaching $6 \mu \times 9 \mu$ in dimensions. Tetrasporangia densely scattered on both sides of frond, cruciate, roundish in shape in surface view, 15–45μ in dimensions, ovoidal or somewhat elongated oblong and $36 \mu \times 42 \mu$ in the maximum dimensions in transverse section, surrounded by somewhat modified cortical cells. Cystocarps abundantly scattered over both surfaces of frond, exceedingly low dome-like in shape, 0.9 mm in height, less than 2.3 mm in diam., non-rostrate, occasionally slightly concaved at the top; pericarp fairly thick, built up of many-layered cells, of which the outermost pigmented ones are anticlinally erect, whereas inner colorless ones are compressed; gonimoblast consisting of large parenchymatous cells relatively poor in protoplasmic content, connected to the pericarp by several nutritive filaments; mature carpospores roundish or more or less elongated in shape, 28–36μ or rarely up to 48μ in diam., containing a reddish stellate chromatophore; antheridia unknown.

According to a personal communication from Dr. Takamine, this alga was first collected by means of a drag-net from a depth of about 10 m at Sugashima, Ise Bay in early summer. Dr. Segawa informs that it grows in the sublittoral zone at Kôzu-shima, Izu Islands.

16. *Gracilariopsis vermiculophylla* Ohmi

Ohmi, Contributions to the knowledge of Gracilariaceae from Japan. II, 1956, P. 271, figs. 1–4, pl. 1–2.

Japanese name: *Ogo-modoki.*

Type: *Ohmi* 200, ♂, Gomejima, Lake Akkeshi, Prov. Kushiro, Hokkaido, Sept. 1955.

Material examined: *Ohmi* 201, ♀, Gomejima, Lake Akkeshi, Sept. 1955; *Ohmi* 202, ⊕, Gomejima, Lake Akkeshi, Sept. 1955; *Ohmi* 203, ⊕, Gomejima, Lake Akkeshi, July 1955; *Ohmi* 204, coexisting ⊕, ♂, Gomejima, Lake Akkeshi, July 1955.

Frond solitary or tufted, arising from a very small callous disc, usually 4–30 cm but sometimes up to 80 cm in length, cylindrical throughout, slightly flexuous; dark red or rather blackish in color, cartilaginous in substance, often adhering imperfectly to paper upon drying; main axis percurrent; branches long-attenuated, issuing alternately on all sides from the main axis or sometimes one-sidedly, mostly with patent, sometimes even rectangular axils, branching up to four times, usually alternately but sometimes also subdichotomously, branches of every type tapering towards apex, hardly constricted at the base except those at the lower portion of the plant, 4.2–17 cm in length in the first order branches, 0.5–4 cm in the second, and shorter than 0.5 cm in the third order, the last one being simple, very short ramulus.

The main axis in the middle portion of the frond, in transverse section, consists in the medulla of 12–13 layers of large, round subisodiametric cells, up to 350μ diam, with walls 5–7μ to 15μ thick; outer cells of the medulla merging gradually into a 2–3

layered subcortex composed of ovoidal cells, 30 μ high, 12–15 μ thick. Medullary cells contain several transparent, highly refractive globules, round or pod-like in shape, up to 75 $\mu \times 60 \mu$ in dimensions; cystocarps subglobose, protruding up to 1.2 mm diam., somewhat rostrate, ostiolate and a little basally constricted, scattered on all sides of branches, often aggregated, with a large gonimoblast parenchyma of small, densely massed, richly protoplasmic cells producing dense, radiating chains of ovoid carpospores almost fully filling the cystocarpic cavity; carpospores roundish or more or less elongated, 30–50 μ in length, containing a conspicuous stellate, central body, nourished only by the gonimoblast, without nutritive filaments; placenta elongated and not lobed. Pericarp 130–150 μ thick, its cortex being composed of two layers of cells, outermost one is 9–15 μ high, 3–5 μ thick, while inner one is usually flat in shape, 8–12 μ high, 4–6 μ thick. Antheridia formed in cavities all over the surface of frond, but occasionally on slightly swollen, somewhat vermiform upper branches; cavities deep, open, conceptacular pockets mostly with a broad opening, 70–150 μ deep and 45–120 μ wide, well-separated by mediately anticlinally modified cortex; tetrasporangia scattered over the surface of frond, circular in shape as seen from surface, up to 42 μ diam., cruciately divided, rose-red in color, borne in a somewhat nemathecially modified cortex with elongated outer cortical cells which are up to 60 μ high and 42 μ thick in transverse view; these three kinds of reproductive organs are, of course, ordinarily formed on different plants.

In some specimens, tetrasporangia and antheridia occurred mixed together. These were scattered over the surface of the frond separately or gathered in small irregular groups which show no elevation above surface. When occurring solitarily the antheridial cavities are broadly urn-shaped or deep pocket-like, well separated from others by somewhat modified cortical cells, but when packed together, oblong. They have a somewhat narrowed opening and are about 45 μ to 70–150 μ deep, 24 μ to 45–120 μ wide in transverse section and 90–150 μ deep, 50–60 μ wide in longitudinal section.

The discovery of the present species is reported with a detailed description and remarks in the writer's previous paper cited above.

17. ***Gracilariopsis rhodotricha*** Dawson

Pl. X, A–B, and Text-fig. 23.

Dawson, Northeast Pacif. Gracilariaceae, 1949, p. 47, pl. 19, figs. 3–7. *Gracilaria confervoides* (L.) Grev., as interpreted by Taylor in Pacif. Mar. Alg. Allan Hancock Exped. to the Galapagos Isl., 1945, p. 230.

Japanese name: *Hoso ogo-modoki* (n. n.).

Material examined: *Chihara*, Nabeta near Shimoda, Shizuoka Pref., July 1955 (*Herb. Ohmi* 57–61, ♀; 62–67, ⊕).

Frond cylindrical throughout, forming entangled clusters or masses, arising from

a small disc, 11 cm in length, rarely up to 1.4 mm in diam. though seldom exceeding 1 mm, scarcely stipitate; branching generally irregular, alternate or secund in places; primary axis scarcely traceable; branches issued on all sides with patent axils at rather short intervals, mostly 1–10 mm in distance; bramchlets tapering towards apex, mostly slightly contracted at the base though in some cases considerably contracted; very slender in texture, purple or somewhat greenish in color, collapsing completely and adhering fairly evenly to paper on drying; frond in transverse section consisting of a medulla of large colorless cells with thin walls usually less than 8 μ, rarely up to 17 μ in thickness, roundish, up to ca 180 μ in diam. in the central cells, gradually becoming smaller in diameter towards the exterior region, and of an infracortex of 2–3 layers of cells, somewhat longitudinally elongated, bounded by a cortex of 1–2 layers of pigmented cortical cells, 4–6 $\mu \times$ 12–15 μ in dimensions, anticlinally erect, with numerous hairs on the surface.

Tetrasporangia scattered among the surface layer of frond, ovate to oblong in transverse section, measuring up to 40 $\mu \times$ 48 μ in dimensions, cruciate, not in sori but slightly upheaved above the vegetative surface by modified cortical cells because of their anticlinal elongation. Cystocarps globular, scattered over the greater part of frond, at maturity becoming very large as compared with the thickness of frond, up to 1.5 mm in diam., rostrate; gonimoblast simple, not lobulated, consisting of fairly small parenchymatous cells with rich contents, without nutritive filaments in connection with the pericarp; pericarp 90–120 μ in thickness, consisting of several layers of colorless compressed cells bounded by a cortex of cuboid pigmented cells; carpospores roundish or ovoid, 30–42 μ in diam. at maturity, with a pigmented body in the center. Antheridia borne over almost whole surface of frond in deep pocket-like, anticlinally oblong cavities varying within a wide range in their dimensions (cf. Table 2), surrounded by modified, elongated cortical cells; their measurements are shown in Table 2; antherozoids colorless, roundish or polygonal, 3–6 μ in diam.

Table 2. Measurement of antheridial cavities formed on the same frond which is 962 μ in diam., collected by Chihara at Nabeta near Shimoda, Shizuoka Pref., in July 1955.

No.	Breadth	Depth	No.	Breadth	Depth
1	24 μ	45 μ	13	55 μ	75 μ
2	40	70	14	55	90
3	40	78	15	60	90
4	40	84	16	60	90
5	42	75	17	60	90
6	45	66	18	60	90
7	45	75	19	60	100
8	45	90	20	60	105
9	45	90	21	60	115
10	45	105	22	63	100
11	50	105	23	65	110
12	54	78	24	75	95

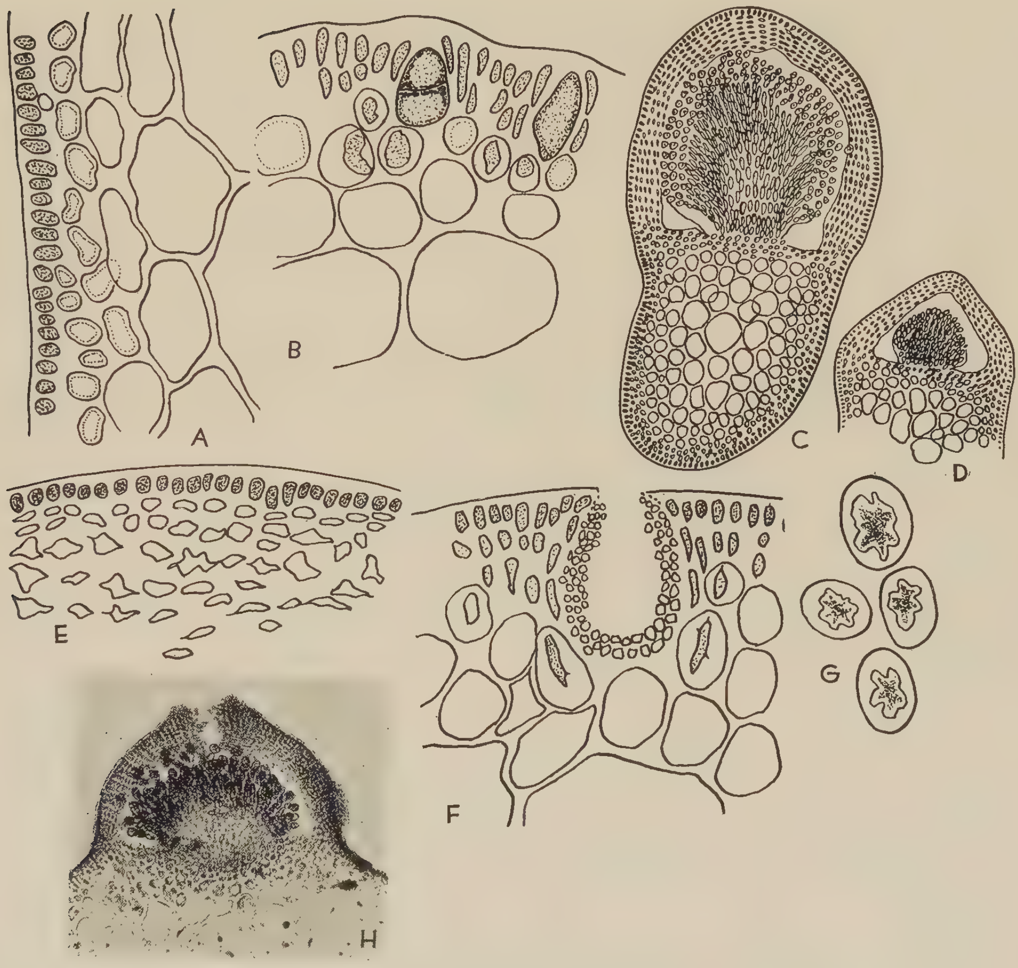


Fig. 23. *Gracilariopsis rhodotricha* Dawson. A. Longitudinal section of a sterile frond. ×284. B. Transverse section of a tetrasporic frond. ×284. C. Section of a mature cystocarp. ×50. D. Section of a young cystocarp. ×50. E. Part of a pericarp in section. ×284. F. Transverse section of an antheridial frond showing the deep pocket-like, conceptacular, antheridial cavity. ×284. G. Detail of carpospores. ×284. H. Microphotograph of a longitudinal section through a mature cystocarp. ×54. (A-H. Plant from Nabeta near Shimoda, Shizuoka Pref., July 1955)

The plant in question appears at first sight to have some likeness in external features to *Gracilariopsis sjöstedtii* (Kylin) Dawson as compared with a number of herbarium specimens and sun-dried specimens of that species. In *Gracilariopsis sjöstedtii*, however, the antheridia are described by Dawson (1949, p. 40, pl. 17, fig. 6) to be "borne in a continuous superficial layer arising from the cortex of the entire surface of the thallus," whereas in the present species they are borne in deep cavities as shown in Fig. 23 F, and as understood from Table 2. Moreover, the cortex of the present

species consists of 1–2 layers of pigmented cells, while that of *Gracilariopsis sjöstedtii* consists of 4–6 layers (cf. Kylin, 1930, p. 55). From *Gracilaria verrucosa* (Huds.) Papenfuss, to which the present species has also a similarity in the external appearance, it differs in lacking nutritive filaments in the cystocarps, in having larger antheridial pits and also in having tetrasporangia embedded in semi-nemathecially modified cortex.

18. ***Gracilariopsis chorda*** (Holm.) Ohmi, comb. nov.

Pl. X, C–D, and Text-fig. 24.

Holm., *Gracilaria chorda* Holm., On Mar. Alg. fr. Japan, 1895, p. 253; Id., La Nuova Notarisia, 1897, p. 23; De-Toni, Syll. Alg. IV, 1900, p. 454; Okam., Nippon Sôrui Mei-i. Ed. 1, 1902, p. 39; Id., Icon. Jap. Alg. IV, 1918, p. 41, pl. 161; Id., Nippon Kaisô-shi, 1936, p. 629.

Japanese name: *Tsuru-shiramo.*

Material examined: *Chihara*, Susaki near Shimoda, Shizuoka Pref., Apr. 1955 (*Herb. Ohmi* 20–23, 24a. ♀); *Chihara*, Susaki near Shimoda, Shizuoka Pref., Apr. 1955 (*Herb. Ohmi* 24b, sterile); *Ueda* 5, sterile, Enoshima, Kanagawa Pref., June 1951; *Tokida* 3c, ⊕, Seto-kanayama, Wakayama Pref., Apr. 1938; *Sugiyama*, Chiba Pref., Aug. 1906 (*Herb. Yendo* 318, ⊕).

Frond solitary or caespitose, arising from a small disc, flagelliform, cylindrical throughout, 60–110 cm long; main axis more or less traceable, thickened at the middle portion up to 2–3 mm in diam., attenuated below into a slender short stipe ca 6 mm in length and tapering above into the filiform apical portion, provided on all sides with similarly shaped alternate branches; branches generally simple and naked, but sometimes loaded with slender filiform branchlets; several long slender young branchlets are frequently observed to arise from a single branch apex; rose purple in color and succulent in substance while fresh, becoming much collapsed and adhering firmly to paper on drying; frond in transverse section consisting of a medulla of large (612-700 μ in diam.), almost empty cells with a wall up to 15 μ thick, covered with sharply defined thin cortex consisting of 2–3 layers of somewhat anticlinally arranged cells, 4–8 $\mu \times$ 9–12 μ in dimensions, without hairs. Tetrasporangia scattered over the whole surfaces of frond, among slightly modified cortical cells, ordinarily oblong in shape in transverse section, 15–30 $\mu \times$ 33–60 μ in dimensions, cruciate. Cystocarps hemispherical, dome-like in appearance, slightly or non-rostrate; gonimoblast simple, not lobulated, consisting of small-celled parenchymatous tissue, without nutritive filaments; pericarp up to 175 μ in thickness; carpospores globular or ovoid in shape, 30–50 μ in diam., containing one or two conspicuously stellate chromatophores. Antheridia unknown.

The above description is a modification of that given by Okamura in 1918.

As to the habitat, Mr. Chihara advises by letter that the plant grows on rocks and boulders on sandy bottom about one meter below the low tide mark, protected from

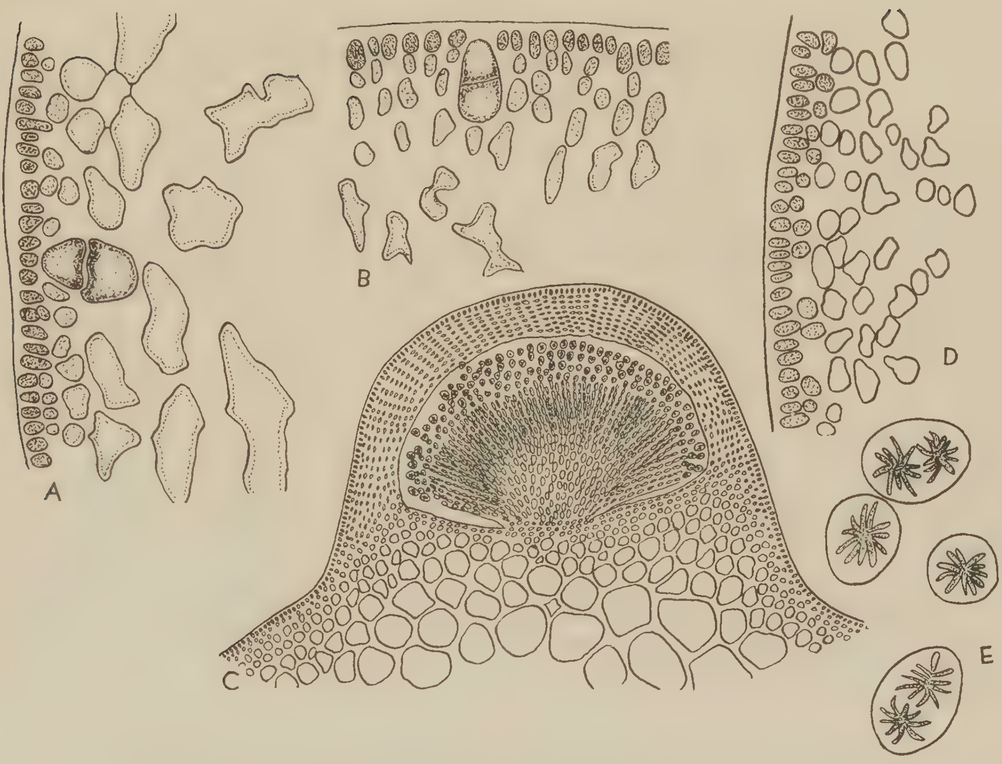


Fig. 24. *Gracilariopsis chorda* (Holm.) Ohmi. A. Longitudinal section of a tetrasporic frond. ×284. B. The same tetrasporic frond in transverse section. ×284. C. Section of a mature cystocarp. ×50. D. Part of the pericarp in a section of a cystocarp. ×284. E. Detail of carpospores. ×284. (A-E. Plant from Susaki near Shimoda, Shizuoka Pref., Apr. 1955).

the open sea, intermixed with *Gracilaria gigas* Harvey, or growing in isolation at places in estuarine waters which are generally deeper than the latter's habitat.

The fact that the present species is destitute of the nutritive filaments connecting the gonimoblast and the pericarp was already noticed by Okamura in 1918. Present writer could confirm their absence in a specimen from Susaki made available by the the kindness of Mr. Chihara. It bears some resemblance in external appearance to *Gracilaria blodgettii* from the same locality, but differs in having several filiform branchlets issued from a common branch apex and in having low dome-like, slightly or non-rostrate cystocarps which are showing all the characteristics of *Gracilariopsis*.

IV. ECONOMIC IMPORTANCE OF *GRACILARIA* AND *GRACILARIOPSIS*

(a) General

Gracilaria species have long been used in Japan for food in two ways: First, after washed free from salt water they are eaten either raw or after boiling as a salad or a garnish, or cooked as a vegetable. Second, after sun-bleached and dried they are marketed as a cheap substitute for gelatine or as a supplementary material for the manufacture of agar-agar. However, the gelose extracted by water from *Gracilaria* plants has been considered useless as any important material of the agar industry owing to its weak gelatinizing power. Recent investigations have shown that its gelatinizing power can be much increased by the addition of alkali solution to the extract. So, *Gracilaria* species have now become a very important source of agar-agar being employed as a principal material of the agar industry in Japan as well as in Australia, America, South Africa, etc.

Before entering into further practical accounts on *Gracilaria* plants, agar production in Japan and foreign countries will be briefly outlined in the following three tables.

Table 3. Annual output and exported amount of Japanese agar-agar in the past twenty two years.

Year	Output	Exported amount	Exp./Outp.	Year	Output	Exported amount	Exp./Outp.
	(in 1,000 lbs.)				(in 1,000 lbs.)		
1934	5,150	2,790	54.2%	1945	1,600	99	6.2%
1935	5,540	3,355	60.6	1946	610	188	30.8
1936	?	3,931	?	1947	1,000	593	59.3
1937	5,900	3,537	59.9	1948	1,500	892	59.5
1938	5,750	3,380	58.8	1949	2,800	688	24.6
1939	6,000	2,986	49.8	1950	2,200	?	?
1940	5,500	2,611	47.5	1951	3,300	1,981	60.0
1941	3,700	1,430	38.6	1952	4,350	1,605	36.9
1942	3,600	829	23.0	1953	5,200	2,220	42.7
1943	4,400	513	11.7	1954	4,060	1,521	37.5
1944	2,600	142	5.5	1955	3,650	3,000	82.2

As understood from Table 3, the Japanese agar-agar to as much as 5.5～82.2% of its annual output has been exported yearly to foreign countries including the United Kingdom and the United States, which, in the amount of Japanese agar import have ranked higher than nearly fifty other countries.

Table 4. Amount of agarophytes supply and agar-agar production per factory in Japan before and after World War II.

Year	A	B		C	
	Number of factories	Amount of agarophytes supply (air-dry weight in 1,000 *kan*. 1 *kan*= 3.75 kg)	B/A (1,000 *kan*)	Amount of agar production (weight in 1,000 lbs.)	C/A (1,000 lbs.)
1935	449	3,164	70.5	5,540	12.3
1936	512	3,319	64.8	5,621	11.0
1937	520	3,241	62.3	5,900	11.3
1938	528	3,368	63.8	5,750	10.9
1939	623	3,565	57.2	6,000	9.6
D: Average of five years	526	3,331	63.7	5,762	10.9
1950	629	1,218	19.4	2,200	3.5
1951	676	1,805	26.7	3,300	4.9
1952	486	1,990	40.9	4,350	8.9
1953	560	2,286	40.8	5,200	9.3
1954	484	2,186	45.2	4,060	8.4
1955	507	2,633	51.7	3,650	7.2
E: 1956	507	2,592	50.9	3,983	7.8
E/D	97%	78%	79%	69%	72%

Table 5. Estimated average annual production of agarophytes and agar-agar in various countries, and probable amount of agar-agar exported annually from them.

Countries	Agarophytes production (in 1,000 *kan*)	Agar production (in 1,000 lbs.)	Probable amount of exported agar (in 1,000 lbs.)
Australia	20	50-100	—
Canada	?	—	—
Chile	?	400	100
China	100	150	—
Denmark	1,170	1,000-1,200	500-550
Germany	?	20	—
Indonesia	?	?	—
Japan	2,400	4,000-5,000	2,500
Java	?	—	—
Korea	300	300-800	300-500
Mexico	10	50	—
New Zealand	50	110	—
South Africa	10	?	—
Spain	8	400-500	250
Sumatra	?	—	—
United Kingdom	?	?	—
U. S. A.	200	200	—
U. S. S. R.	100	440	—

(b) Industrial utilization of *Gracilaria* plants in foreign countries

Australia is one of themain countries producing *Gracilaria*-agar. According to

Chapman (1950) agar is manufactured in New South Wales from *Gracilaria confervoides* which grows very abundantly in Botany Bay. It has been estimated that an annual production of 100 tons of agar is possible in New South Wales. This amount is said to be sufficient for Australian home needs. The following table gives the industrial uses of agar in Australia in 1938.

Table 6. Uses of agar in Australia (Ferguson Wood, 1946).

Industry	Lbs. per annum
Meat preserving	99,350
Confectionery	33,235
Spices and condiments	24,416
Chemical, medical, etc.	1,459
Jams and vegetable pastes	1,459
Aerated waters and cordials	336
Total	160,255

G. confervoides is reported to form the basis of a small agar industry in South Africa (Issac et Molteno, 1953). It is also used in the agar industry on the Atlantic coast of North America and along the Gulf of Mexico coasts (Zaneveld, 1955). In Ceylon, both *G. confervoides and G. lichenoides* are sold after having been washed and dried as 'Ceylon Moss' at Rs. 2/50 per 1b. in dry weight. They are employed as the chief source of agar and several thousand pounds are produced in Ceylon (Zaneveld, 1955).

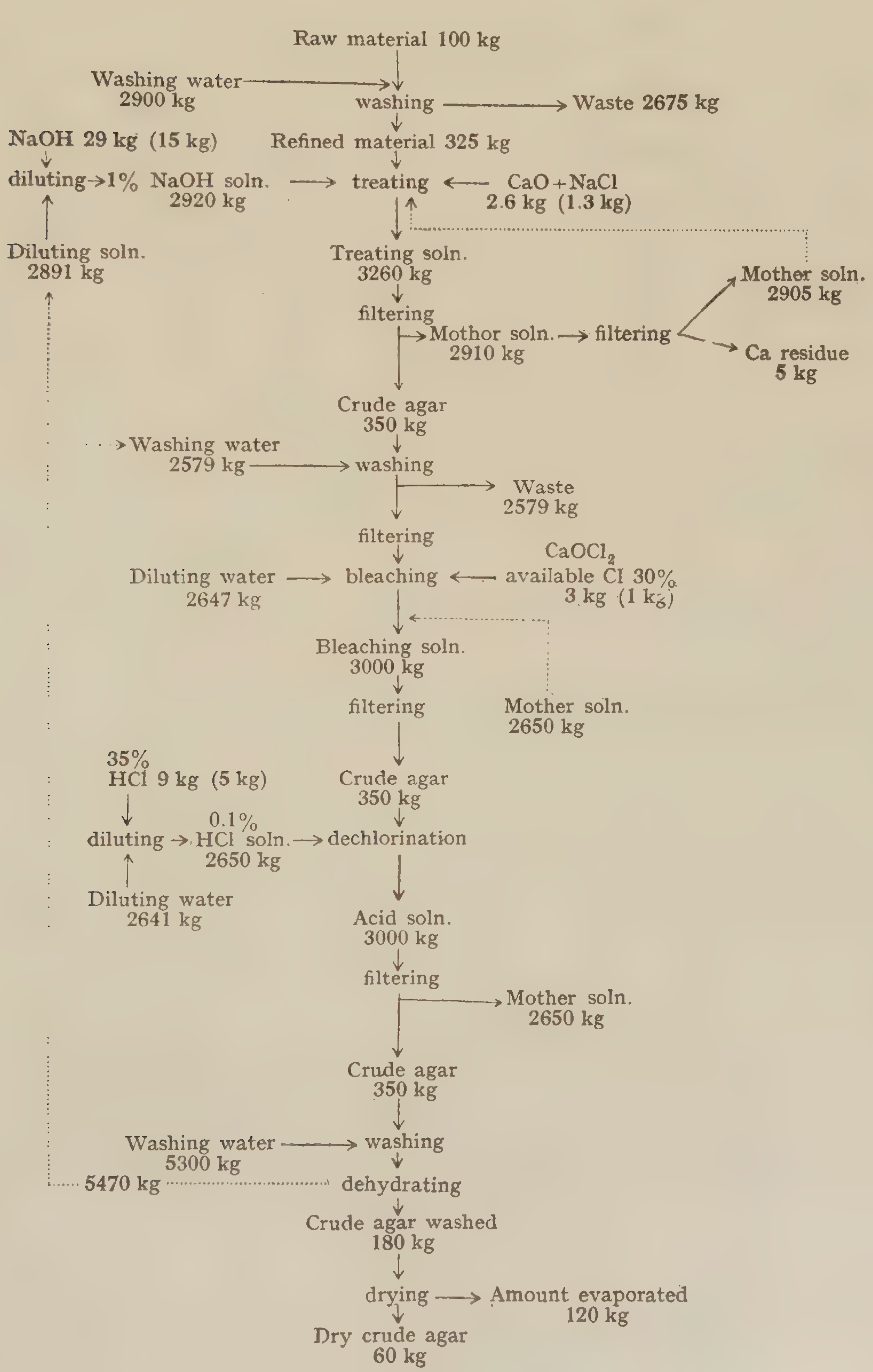
(c) Manufacture of agar-agar from *Gracilaria* in Japan

Gracilaria species have been used in Japan as one of the principlal materials of agar manufacture since more than twenty years ago. Details of the process of agar manufacture from *G. verrucosa* are shown on page 55 in the scheme given by Kojima *et al.* (1952).

Table 7 gives details of the so-called "industrial agar" manufacture in the past 18 years in Japan. This kind of agar is manufactured in a factory equipped with latest chemical apparatuses. As is known from the table, *Gracilaria verrucosa* was used as the only source of agar by the nine manufacturers among the seventeen which were in operation in 1957. This is probably due to the fact that *Gracilaria* is not only lower in price but also easier to obtain in the market than *Gelidium*.

(d) Chemical properties of *Gracilaria* plants from Hokkaido

Ohmi *et* Kuroda (1955) reported the results of their chemical analyses of *Gracilaria verrucosa* from various localities in Japan and *Gracilariopsis sjöstedtii* from Carpenteria, California, as shown in Table 8.



Flow diagram of crude agar manufacture from *G. verrucosa* (Kojima *et al.*, 1952)

Table 7. Industrial agar manufacture in Japan.

No	District	Name of Manufacturer	Annual output of agar from 1940 to 1957 (1,000 lbs.)																	
			1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957
1	Karafuto	Karafuto Kanten	400	400	400	400	400	400												
2	Hokkaido	Mitsuya Reitô										40	40	40	40					
3	〃	Tôyô Kagaku											24	24	24					
4	Miyagi	Asahi Kanten											24	24						
*5	Fukushima	Fuji Kagaku															24	24	24	24
*6	Chiba	Tenso Kogyô	60	60	60	60	60	60	60	60	60	75	75	75	120	120	120	120	120	120
*7	〃	Showa Kenkô														36	36	36	36	36
*8	〃	Asahi Shokuhin									60	60	60	60	60	60	60	60	60	324
*9	〃	Tôhô Kasei							60	60	60	60	60	60	60					
*10	Tokyo	Asahi Kanten															30	30		
*11	〃	Tokyo Kanten												24	24	24				
*12	〃	Nippon Agar																	240	240
*13	〃	Tamagawa Kanten																		180
14	〃	Nippon Kaisô Kôgyô																		120
15	〃	Daikôsha											60	60						
*16	〃	Shôei Sangyô														46	46	46	46	46
17	Shizuoka	Kaihô Kanten									60	60	60	180	180	180	180			
18	〃	Kamo Gyoren									20	20	20	20	20	20	48	48	48	48
19	〃	New Agar											80	80	80					
20	〃	Fusô Suisan													24					
21	〃	Nihon Agar									30									
22	〃	Nihon Shokuhin										60	60							
*23	〃	Nisshin Kasei									48	48	48	48	48	48	48	60	60	60
24	〃	Suzuki Kagaku															30	30	30	60
25	〃	Taiyô Reizô								75	75	75	75	75	120	120	120	120	120	120
26	Toyama	Tanio Kagaku										48	48							
27	Nagano	Koike Hisaya																25	25	25
28	〃	Kaken Kôgyo																		60
29	Aichi	Tôyô Kanten											30	30						
30	〃	Chûbu Ryômatsu Kôgyô																120	120	120
*31	Osaka	Settsu Nôson Kôgyô															180	180	180	180
32	Nagasaki	Fuji Kakô											60							
33	〃	Tôyô Kanten										50	50							
34	Kumamoto	Kumamoto Kanten																		20
Total output per each year			460	460	460	460	460	460	120	195	413	496	874	800	802	654	922	899	1,139	1,813
Number of manufacturers			2	2	2	2	2	2	2	3	8	11	17	14	12	9	12	13	13	17

* *Gracilaria verrucosa* is only used as the source of agar by these manufacturers.

Table 8. Chemical composition of *Gracilaria* plants from various localities in per cent of anhydrous material.

Species	*Gracilaria verrucosa*						*Gracilariopsis sjöstedtii*
Locality	Hakodate	Nemuro	Akkeshi	Funabashi	Kumamoto Pref.	Aichi Pref.	Carpenteria, Calif.
Date of collection	3/IX, 1954	10/VIII, 1954	19/VI, 1954	30/VI, 1954	30/VII, 1954	3/VIII, 1954	22/VIII, 1954
Ash	8.58	11.27	12.66	11.12	11.05	13.17	13.70
Crude protein	24.03	19.21	20.36	16.43	23.73	19.65	15.33
SO_3	4.51	7.09	6.28	5.88	4.55	6.54	5.72
Crude fibre	8.56	4.97	9.90	7.98	7.80	6.09	5.02
Ether extract	0.22	0.16	0.07	0.13	0.23	0.25	0.16
Agar substance	38.81	42.36	41.81	41.14	39.21	40.53	49.91

As observed in the above table, *Gracilariopsis sjöstedtii* from Carpenteria, California proved to excel the others in the content of agar substance which amounted to 49.91% of anhydrous matter. Agar content of six samples of *Gracilaria verrucosa* from Japan ran from 38.81 to 42.36%.

The seasonal variation of the chemical constituents of *G. verrucosa* from Tôkai, Lake Akkeshi was reported by Kuroda *et* Matsumura (1954) as shown in Table 9.

Table 9. Seasonal variation of the chemical constituents of *Gracilaria verrucosa* from Lake Akkeshi in 1953 (in per cent of anhydrous matter).

Constituents	Date of sampling					
	June 15	July 15	Aug. 15	Sept. 15	Oct. 15	Nov. 15
Ash	10.63	24.33	25.87	27.69	27.14	26.15
Crude protein	17.68	15.69	14.44	11.69	13.88	18.00
SO_3	5.15	10.06	9.91	12.18	7.97	9.14
Crude fibre	5.50	5.87	8.38	7.53	8.74	6.23
Ether extract	0.09	0.11	0.09	0.09	0.09	0.10
Agar substance	42.75	45.43	45.60	47.84	47.10	44.75

As understood from the table, the chemical constituents of this plant did not show any remarkable variation by seasons at least from July to October.

(e) Ecology of *Gracilaria* plants and their production in Japan

In Japan, *Gracilaria verrucosa* grows most abundantly in Lake Akkeshi, Hokkaido, and in Tokyo Bay along the northeastern side. In Lake Akkeshi it occurs in great profusion, being detached from the substrata and lying loosely on the sandy and muddy bottom among the vegetation of *Zostera marina*; after a strong wind it is often found cast ashore in a considerable amount. Such cast up plants show various color graduations from dark red to greenish-brown or almost white. Limnological observations and bottom soil analyses of Lake Akkeshi in Prov. Kushiro and Lake Fûren (includ-

ing Lake Onne) in Prov. Nemuro were carried out by Kuroda *et* Okesaku (1956) with the object of studying the ecology of *Gracilaria verrucosa*. They state in the conclusion of their report that: (1) The water of these lakes is under constant agitation on account of their shallowness, constant inflowing of rivers, and the tidal in- and outflow of the sea-water; (2) The salinity of these lakes is consequently rather low; (3) The bottom is mostly muddy and the water is always turbid; (4) Nutrient substances are poor in the bottom as compared with other brackish lakes while they exist abundantly in the water being in a state to be absorbed easily by algae; (5) These lakes are to be classified as eutrophic brackish-water lakes.



Fig. 25. Map showing Lake Akkeshi, Hokkaido.

In Lake Akkeshi, fishermen harvest *G. verrucosa* from the end of September to the beginning of October. Table 10 shows the annual yield of *G. verrucosa* from Lake Akkeshi for the past ten years while Table 11 shows the same from 16 districts of Japan for the past four years.

Table 10. Annual yield of *Gracilaria verrucosa* from Lake Akkeshi (air-dry weight in *kan*=3.75 kg).

1947	7,050	1952	423,344
1948	13,982	1953	60,126
1949	36,000	1954	107,872
1950	32,480	1955	62,470
1951	122,320	1956	117,660
Average	98,330		

Table 11. Annual yield of *Gracilaria verrucosa* from 16 districts of Japan (air-dry weight in *kan*).

District	Year			
	1953	1954	1955	1956
Hokkaido	63,652	113,738	69,462	119,862
Miyagi	50,084	58,506	62,875	23,571
Fukushima	8,550	7,700	8,400	8,000
Chiba	?	?	?	363,276
Tokyo	?	?	?	3,000
Shizuoka	14,000	11,000	12,000	?
Aichi	24,739	16,339	300	3,250
Mie	2,615	1,710	3,220	?
Shimane	26,000	20,800	8,500	11,000
Okayama	8,360	9,190	20,900	23,830
Saga	1,645	14,863	5,934	8,000
Nagasaki	?	?	?	2,140
Kumamoto	11,070	10,380	14,210	?
Ōita	30,000	30,000	30,000	30,000
Miyazaki	?	?	?	2,500
Kagoshima	?	?	?	300
Total	240,715 + α	294,326 + α	235,801 + α	601,729 + α

The annual yield of *G. verrucosa* from Lake Akkeshi in the past four years, as shown in the tables, corresponds to 89～98% of the annual total production of the alga from Hokkaido. Hokkaido is second only to Chiba in the annual yield of this alga in 1956 when Lake Akkeshi produced 98% of the total yield from Hokkaido. Thus, Tokyo Bay and Lake Akkeshi are most important from the standpoint of the production of *Gracilaria verrucosa*. Further studies on the ecology and artificial propagation of this agarophyte and other related species in these waters are pressingly needed for the development of agar industry in Japan. The present contribution is believed to be a useful stepping-stone for making progress in such studies.

V. SUMMARY

For these several years the writer under the guidance of Professor J. Tokida has been working on a taxonomic study of *Gracilaria* and related genera hitherto known to occur in Japan and neighboring waters. In Part I of the series of contributions published in 1955, the writer reported his discovery of antheridia in *Gracilaria textorii*, and stated that it was identical with *Gracilaria vivesii*; in Part II, description was given of a new species, *Gracilariopsis vermiculophylla*, which was collected in Lake Akkeshi, Hokkaido.

In the present paper are given full descriptions of all the species of *Gracilaria* and *Gracilariopsis* known to occur in Japan and vicintiy. An analytical key to all of these species is also given. The following data reported herein are worthy of special mention.

(1) Fifteen species and one forma of *Gracilaria* and three species of *Gracilariopsis* are treated herein, of which one species of *Gracilariopsis*, *G. rhodotricha* Dawson, is new to Japan, one species of *Gracilaria*, *G. salicornia* (Ag.) Dawson, is new to Ryûkyû, one *Gracilariopsis*, *G. chorda* (Holm.) Ohmi, is newly combined species, and *Gracilaria sublittoralis* is given a description herein for the first time.
(2) Antheridia of the following three species are first observed and described herein: *Gracilaria blodgettii*, *G. bursa-pastoris* and *G. arcuata*.
(3) Tetrasporangia of the following two species are first observed and described herein: *Gracilaria edulis* and *G. incurvata*.
(4) Coexistence of antheridia and tetrasporangia on one and the same frond, which was reported in *Gracilariopsis vermiculophylla* in the previous paper (1956), is again observed and described herein with the material of *Gracilaria blodgettii* and *G. bursa-pastoris*.
(5) Gland-like cells of the following two species are first observed and described herein: *Gracilaria crassa* and *G. salicornia*.
(6) In view of the economic importance of *Gracilaria* plants, some brief considerations on their use are offered on the basis of the latest statistics.

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VII. INDEX OF LATIN NAMES

Page numbers where descriptions appear are indicated in thick type and those where synonyms appear are given in italics.

EXPLANATION OF PLATES

Plate I

Gracilaria verrucosa (Huds.) Papenfuss

A. Tuft of tetrasporic fronds from Oshoro, Hokkaido.
B. Cystocarpic plant from Susaki near Shimoda, Shizuoka Prefecture.
C. Cystocarpic plant from Oshoro, Hokkaido.
D. Tuft of male fronds from Oshoro.

Gracilaria gigas Harv.

E. Cystocarpic plant from Nabeta near Shimoda, Shizuoka Prefecture.


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Plate II

Gracilaria gigas Harv.

A. Tuft of tetrasporic fronds from Chiba Prefecture.

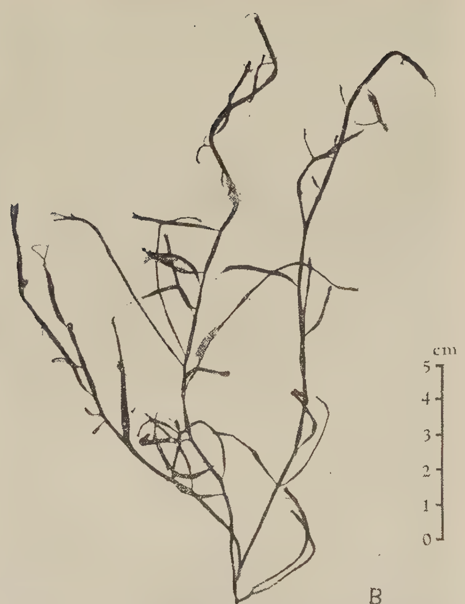
Gracilaria blodgettii Harv.

B. Tetrasporic plant from Susaki near Shimoda, Shizuoka Prefecture.
C. Cystocarpic plant from the same locality as above.
D. Male plant from Tung-shih, Chia-I Pref., Formosa.

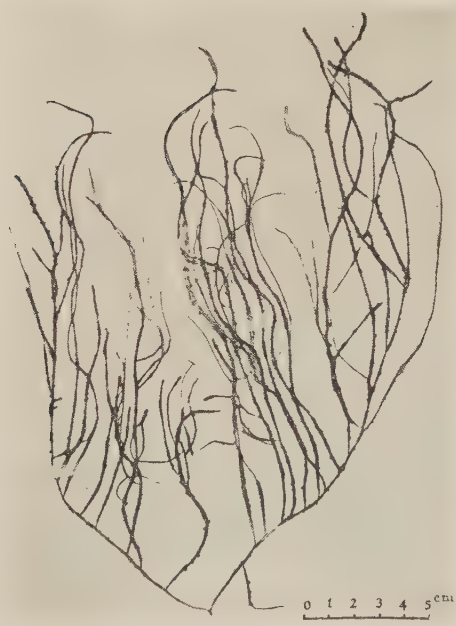
Plate II



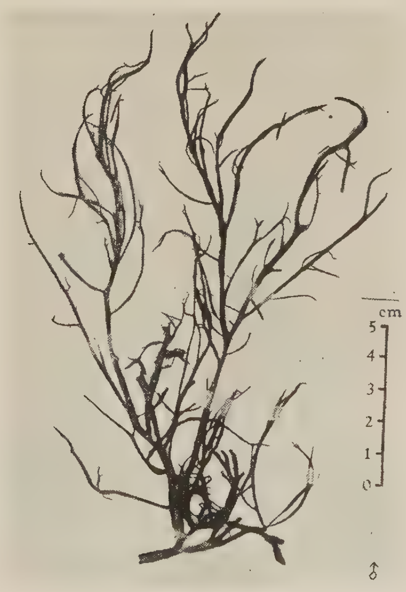
A



B



C



D

Plate III

Gracilaria blodgettii Harv.

A. Plant from Tung-shih, Chia-I Pref., Formosa bearing both tetrasporangia and antheridia on the same branch.

Gracliaria edulis (Gmel.) Silva

B. Tetrasporic plant from Ryûkyû. × 1/2.

Gracilaria bursa-pastoris (Gmel.) Silva

C. Tuft of tetrasporic fronds from Shirahama, Wakayama Prefecture.
D. Cystocarpic plant from the same locality.

Plate III



A



B



C



D

Plate IV

Gracilaria bursa-pastoris (Gmel.) Silva

A. Male plant from Himi, Toyama Prefecture.
B. Plant from Chiba Prefecture bearing both tetrasporangia and antheridia on the same branch.

Gracilaria coronopifolia J. Agardh

C. Young tetrasporic plant from Garanbi, Formosa.
D. Sterile plant from the same locality.

Plate IV



Plate V

Gracilaria arcuata Zanard.

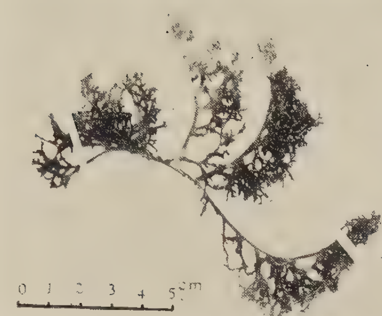
A. Tetrasporic plant from Susaki, Kôchi Prefecture.
B. Cystocarpic plant from Kashiwajima, Kôchi Prefecture.
C. Male plant from the same locality.

Gracilaria crassa Harv.

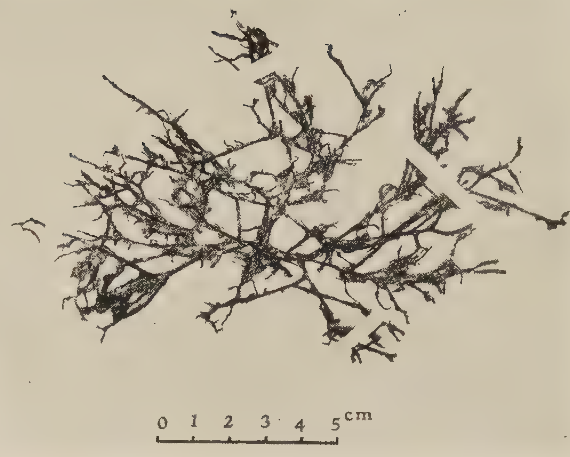
D. Sterile plant from Shinko, Taitung Pref., Formosa.
E. Tuft of tetrasporic plants from Naha, Ryûkyû.

Gracilaria salicornia (Ag.) Dawson

F. Tuft of cystocarpic plants from Itoman, Ryûkyû.



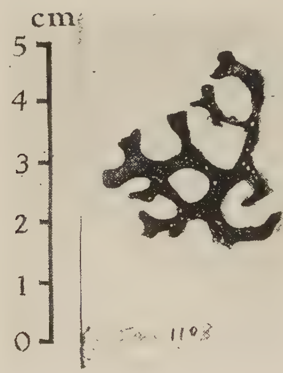
A



B



C



D



E



F

Plate VI

Gracilaria salicornia (Ag.) Dawson

A. Tuft of tetrasporic plants from Itoman, Ryûkyû.

Gracilaria denticulata (Kütz.) Weber van Bosse

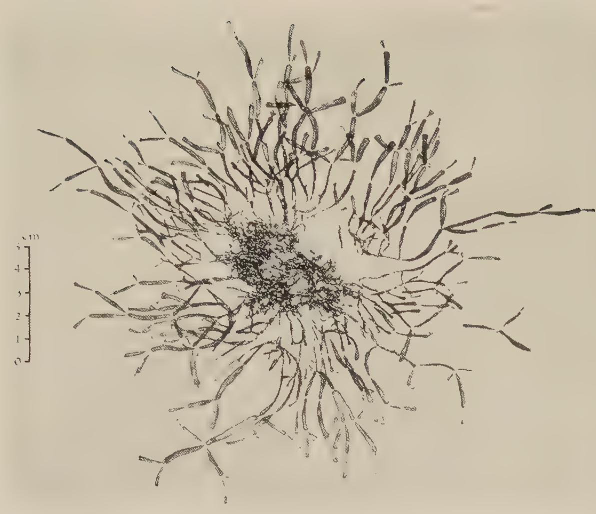
B. Cystocarpic plant from Ryûkyû.

Gracilaria purpurascens (Harv.) J. Agardh

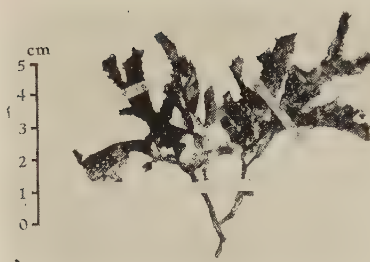
C. Tetrasporic plant from Naha, Ryûkyû.
D. Tuft of cystocarpic plants from the same locality.

Gracilaria purpurascens (Harv.) J. Ag. f. *spinulosa* (Okam.) Yamada

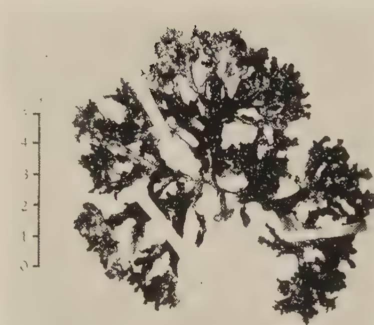
E. Male plant from Tairi, Formosa.



A



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C



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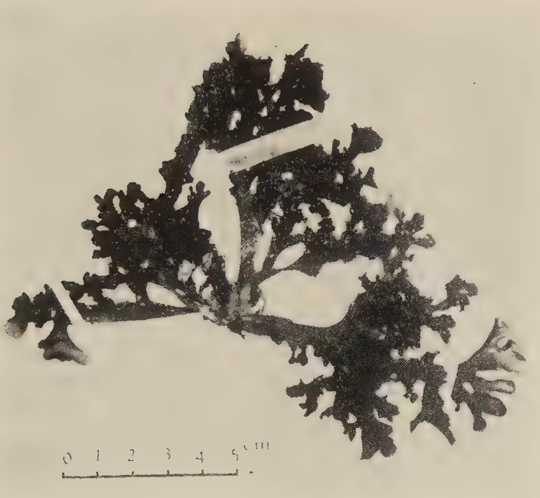
Piate VII

Gracilaria purpurascens (Harv.) J. Ag. f. *spinulosa* (Okam.) Yamada

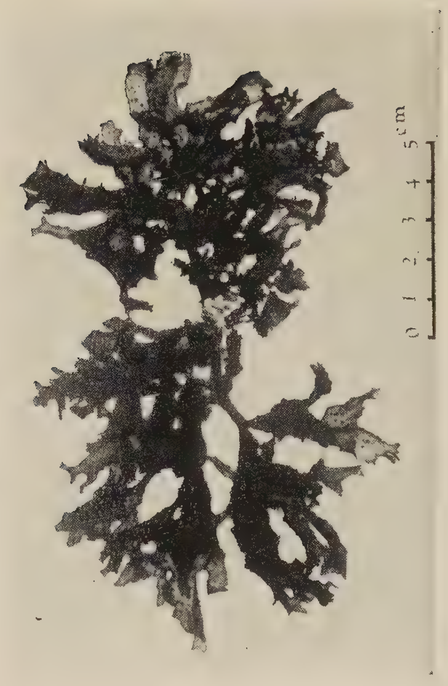
A. Tuft of tetrasporic plants from Tairi, Formosa.
B. Tuft of cystocarpic plants from Fukikaku, Formosa.

Gracilaria punctata (Okam.) Yamada

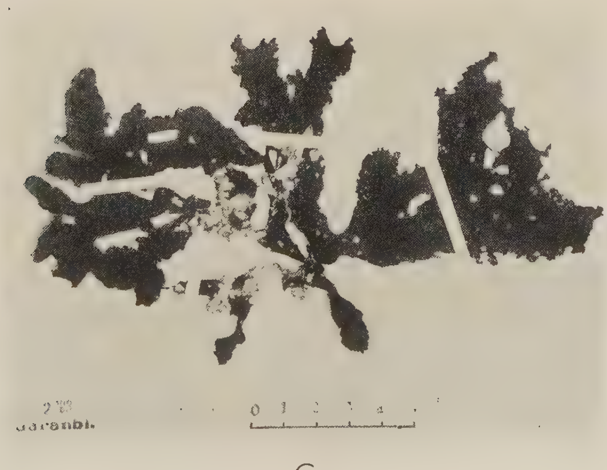
C. Tetrasporic plant from Garanbi, Formosa.



A



B



C

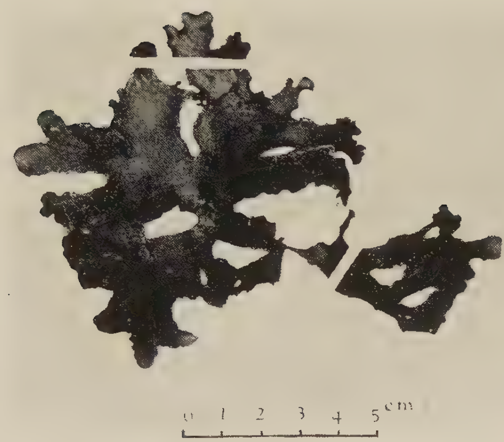
Plate VIII

Gracilaria punctata (Okam.) Yamada

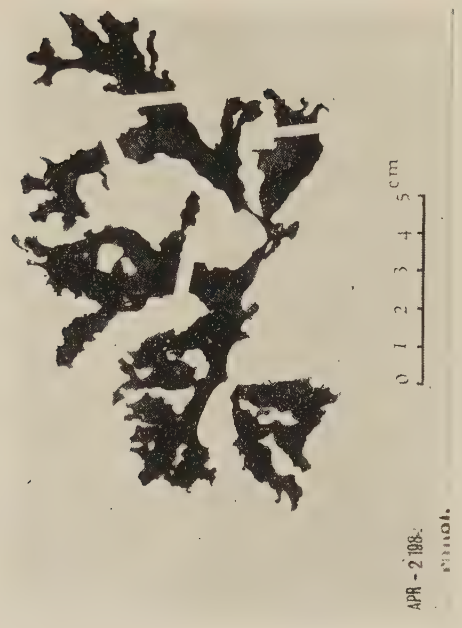
A. Cystocarpic plant from Tairi, Formosa.
B. Male plant from Garanbi, Formosa.

Gracilaria incurvata Okam.

C. Sterile plant from Mitsuhama, Ehime Prefecture.
D. Tuft of sterile plants from Minatoyama, Ehime Prefecture.



A



B



C



D

Plate IX

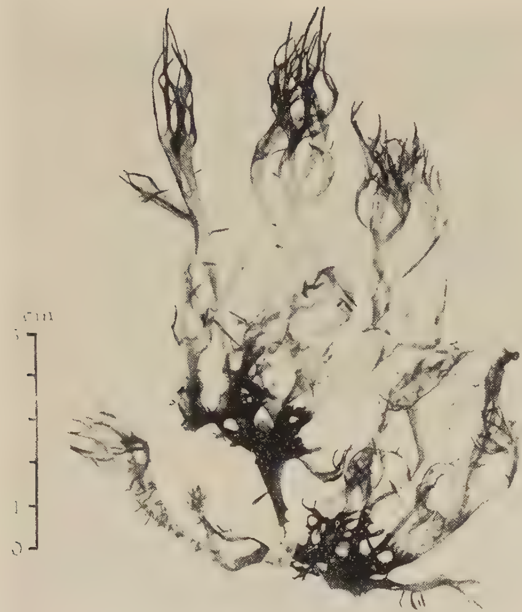
Gracilaria incurvata Okam.

A. Tuft of tetrasporic plants from Mitsuhama, Ehime Prefecture.
B. Tuft of cystocarpic plants from Gogo-shima, Ehime Prefecture.

Gracilaria sublittoralis Yamada et Segawa

C. Tetrasporic plant from Kôzu-shima, Izu Isl. × ca 1/2.
D. Cystocarpic plant from the same locality. × 5/9.

Plate IX



A



B



C



D

Plate X

Gracilariopsis rhodotricha Dawson

A. Tetrasporic plant from Nabeta near Shimoda, Shizuoka Prefecture.
B. Cystocarpic plant from the same locality.

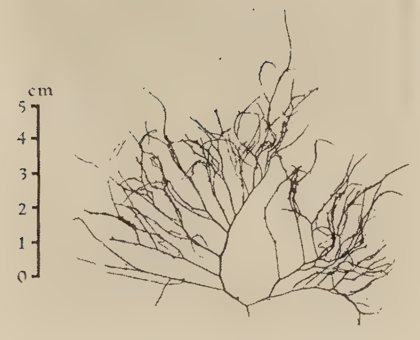
Gracilariopsis chorda (Holm.) Ohmi

C. Sterile plant from Enoshima, Kanagawa Prefecture.
D. Tetarsporic plants from Seto-kanayama, Wakayama Prefecture.

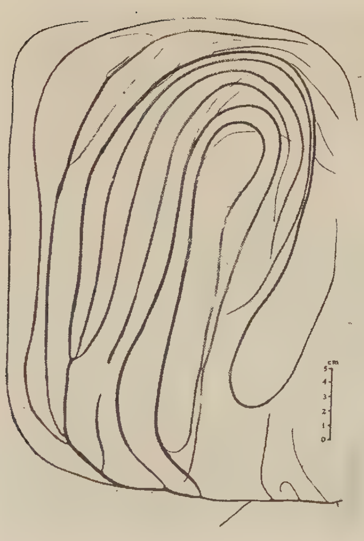
Plate X



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